Chapter 2: Assessment of the Pacific Cod Stock in the Eastern Bering Sea and Aleutian Islands Area

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EXECUTIVE SUMMARY

Summary of Major Changes

Relative to the November edition of last year's BSAI SAFE report, the following substantive changes have been made in the Pacific cod stock assessment.

Changes in the Input Data

1) Catch data for 1964-1977 were incorporated, catch data for 2004 were updated, and preliminary catch data for 2005 were incorporated.
2) Size composition data from the 1974-1977 commercial fisheries were incorporated, size composition data from the 2004 commercial fisheries were updated, and preliminary size composition data from the 2005 commercial fisheries were incorporated.
3) Size composition data from the 2005 EBS shelf bottom trawl survey were incorporated.
4) The biomass estimate from the 2005 EBS shelf bottom trawl survey was incorporated (the 2005 estimate of 603,788 t was up about 1% from the 2004 estimate).
5) Age composition data from the 1996-1997 EBS shelf bottom trawl surveys were incorporated.
6) Length-at-age data from the 1996-1997 EBS shelf bottom trawl surveys were incorporated.
7) A new maturity-at-length schedule was incorporated.
8) Average bottom temperatures from the 1982-2005 shelf surveys were incorporated.

Changes in the Assessment Model

Three alternative models are presented. Model 1 is identical to last year's model, which was developed using the Stock Synthesis 1 assessment software that has formed the basis of the EBS Pacific cod model since 1993. Models 2 and 3 were developed under the new Stock Synthesis 2 assessment software, which uses automatic differentiation (via the ADMB programming language) to minimize the objective function rather than the finite-difference algorithm used in Stock Synthesis 1. In addition, Stock Synthesis 1 and Stock Synthesis 2 differ with respect to several technical details which are described in the main text of this chapter. The primary difference between Model 2 and Model 3 is that Model 2 fixes the natural mortality rate M and the EBS shelf bottom trawl survey catchability coefficient Q at values of 0.37 and 1.00, respectively (identical to the values assumed in Model 1), whereas Model 3 allows the values of these two parameters to be estimated internally.

Changes in Assessment Results

1) Based on Model 3, the estimated 2006 female spawning biomass for the BSAI stock is 334,000 t, up about 13% from last year's estimate for 2005 and up about 13% from last year's F_{ABC} projection for 2006.
2) Based on Model 3, the estimated 2006 total age 3+ biomass for the BSAI stock is 1,050,000 t, down about 19% from last year's estimate for 2005 and down about 9% from last year's $F_{40\%}$ projection for 2006.
3) Based on Model 3, the recommended 2006 ABC for the BSAI stock is 183,000 t, down about 11% from last year's estimate for 2005 and down about 6% from last year's F_{ABC} projection for 2006.
4) Based on Model 3, the estimated 2006 OFL for the BSAI stock is 216,000 t, down about 18% from last year's estimate for 2005.

Responses to Comments of the Scientific and Statistical Committee (SSC)

SSC Comments Specific to the Pacific Cod Assessments

From the December, 2004 minutes: *"The SSC was intrigued by the stock-recruit fits for the periods 1977-1988 and 1989-2002 and we thank the authors for including this analysis. For the 2006 assessment, the SSC asks the authors to explore whether these findings can be used to elevate the BSAI cod stock to tier 1 or 2. If it is deemed that MSY is too variable between periods to apply any MSY estimates to this stock, then next year's assessment should consider potential implications of this variability in stock productivity on estimation of the F35% and F40% reference points."* The Ricker stock-recruitment curves shown in last year's assessment were intended to be illustrative only, because the statistical technique used to compute the parameters of those curves has significant drawbacks, as described in last year's assessment. Therefore, it does not seem advisable to use those parameters as the basis for elevating the BSAI Pacific cod stock to Tier 1 or 2. While statistically valid estimates of stock-recruitment parameters and the associated uncertainties may soon be available for BSAI Pacific cod, it was not possible to develop them in time for this year's assessment. Most assessment effort this year went toward understanding and applying the new Stock Synthesis 2 modeling software. Unfortunately, Stock Synthesis 2 currently supports only the Beverton-Holt stock-recruitment function, although support for the Ricker function will undoubtedly be forthcoming. Regarding the issue of decadal-scale variability in stock-recruitment parameters, no determination has been made as to whether such variability would likely detract from the applicability of any future estimates of MSY or related quantities in the case of BSAI Pacific cod. The subject of nonstationary stock-recruitment relationships is an active area of research at the Alaska Fisheries Science Center, and results of this research may be applicable to future assessments of the BSAI Pacific cod stock. As a first, albeit small, step toward incorporating a stock-recruitment relationship into the provision of fishery management advice, the standard program used to make future projections in all Tier 1-3 BSAI and GOA groundfish assessments now includes an option to fit a Ricker stock-recruitment relationship by assuming that $F_{35\%}$ and $B_{35\%}$ correspond to F_{MSY} and B_{MSY}, respectively. The projections provided in the present assessment make use of this option.

From the December, 2004 minutes: *"The authors are asked to examine interannual variability in cod weight-at-length estimates (index of condition) and potential relationships with cod density, stock-recruit, or environmental conditions. Condition indices have been useful metrics in analyses of the health of Atlantic cod stocks."* Interannual variability of the weight-at-length relationship and condition factor is explored in the "Weight at Length" subsection of the "Data" section and in Figures 2.4 and 2.5.

From the December, 2004 minutes: *"The SSC also requests that the authors provide justification for their assumption that there are no gender-based differences in length-at-age or weight-at-length for Pacific cod. If there is sexual dimorphism in growth, then size-based selection in the fisheries will generate time variations in sex ratios that can have important consequences to the stock's productivity."*

Sex-specific length at age and weight at length is explored in the “Length at Age” and “Weight at Length” subsections of the “Data” section and in Figures 2.2 and 2.3.

From the December, 2004 minutes: *“Lastly, the SSC requests that the assessment authors provide likelihood profiles or similar analyses that illustrate the consistency of model fits to the various input data sources. This is especially important in situations where new data sources (e.g., age data) are incorporated into an assessment model.”* Bivariate profiles of the main components of the log posterior density, focusing on the natural mortality rate and the EBS shelf bottom trawl survey catchability coefficient, are provided in Table 2.17 and discussed in the “Model Evaluation” section.

From the October, 2005 minutes: *“The SSC endorses the use of SS2 for this assessment because it provides the ability to track uncertainty and it is more likely than SS1 to find a global minimum in the fitting procedure. The author encountered major problems in the implementation of this new software due to the complexity of his model but was able to make it work with substantial manual tuning. The SSC encourages the author to implement the stock assessment model directly into ADMB to attain greater flexibility in modeling.”* Two SS2-based models have been developed for the EBS Pacific cod stock. These are described and evaluated in the “Analytic Approach” and “Model Evaluation” sections. Coding an original assessment program directly into ADMB could be an option for future assessments, but was not possible to implement in time for this year’s assessment.

From the October, 2005 minutes: *“The SSC requests a more detailed description of J. Stark’s maturity analysis.”* Methods used in the new maturity study are described in the “Maturity at Length” subsection of the “Data” section. Results of this study are presented and evaluated in the context of previous work in the “Parameters Estimated Independently” subsection of the “Analytic Approach” section.

SSC Comments on Assessments in General

From the December, 2004 minutes: *“In its review of the SAFE chapters, the SSC noted that there is variation in the information presented. Several years ago, the SSC developed a list of items that should be included in the document. The SSC requests that stock assessment authors exert more effort to address each item contained in the list.”* Every reasonable effort has been made to respond to all SSC requests and to ensure that the BSAI Pacific cod assessment complies with the “Guide to the Preparation of Alaska Groundfish SAFE Report Chapters” produced by the Alaska Fisheries Science Center (last revised in June, 2003).

INTRODUCTION

Pacific cod (*Gadus macrocephalus*) is a transoceanic species, occurring at depths from shoreline to 500 m. The southern limit of the species’ distribution is about 34° N latitude, with a northern limit of about 63° N latitude. Pacific cod is distributed widely over the eastern Bering Sea (EBS) as well as in the Aleutian Islands (AI) area. The resource in these two areas (BSAI) is managed as a single unit. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and Gulf of Alaska (GOA). Although at least one previous genetic study (Grant et al. 1987) failed to show significant evidence of stock structure within these areas, current genetic research underway at the Alaska Fisheries Science Center may soon shed additional light on the issue of stock structure of Pacific cod within the BSAI (M. Canino, AFSC, pers. commun.). Pacific cod is not known to exhibit any special life history characteristics that would require it to be assessed or managed differently from other groundfish stocks in the EBS or AI areas.

FISHERY

Catches of Pacific cod taken in the EBS, AI, and BSAI for the periods 1964-1980 and 1981-2005 are shown in Tables 2.1a and 2.1b, 2.2a and 2.2b, and 2.3a and 2.3b, respectively. The catches in Tables 2.1a, 2.2a, and 2.3a are broken down by year and fleet sector (foreign, joint venture, domestic annual processing), while the catches in Tables 2.1b, 2.2b, and 2.3b are broken down by gear type as well. During the early 1960s, a Japanese longline fishery harvested BSAI Pacific cod for the frozen fish market. Beginning in 1964, the Japanese trawl fishery for walleye pollock (*Theragra chalcogramma*) expanded and cod became an important bycatch species and an occasional target species when high concentrations were detected during pollock operations. By the time that the Magnuson Fishery Conservation and Management Act went into effect in 1977, foreign catches of Pacific cod had consistently been in the 30,000-70,000 t range for a full decade. In 1981, a U.S. domestic trawl fishery and several joint venture fisheries began operations in the BSAI. The foreign and joint venture sectors dominated catches through 1988, but by 1989 the domestic sector was dominant and by 1991 the foreign and joint venture sectors had been displaced entirely. Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including trawl, longline, pot, and jig components. Figures 2.1a and 2.1b show areas in which sampled hauls or sets for each of the three main gear types (trawl, longline, and pot) were concentrated during 2004 (Figure 2.1a overlays catch concentrations against NMFS 3-digit statistical areas and Figure 2.1b overlays them against strata used in the EBS shelf bottom trawl survey). To create these figures, the EEZ off Alaska was divided into 20 km $\times$ 20 km squares. For each gear type, a square is shaded if more than two hauls/sets containing Pacific cod were sampled in it during 2004.

The history of acceptable biological catch (ABC) and total allowable catch (TAC) levels is summarized and compared with the time series of aggregate (i.e., all-gear, combined area) commercial catches in Table 2.4. From 1980 through 2005, TAC averaged about 77% of ABC, and aggregate commercial catch averaged about 88% of TAC. In 9 of these 26 years (35%), TAC equaled ABC exactly, and in 5 of these 26 years (19%), catch exceeded TAC (by an average of 4%). Changes in ABC over time are typically attributable to three factors: 1) changes in resource abundance, 2) changes in management strategy, and 3) changes in the stock assessment model. For example, in the assessments for fishery years 1980 through 2005, six different assessment models were used (Table 2.4), though all models since the 1992 fishery year have been based on Stock Synthesis 1. Historically, the great majority of the BSAI catch has come from the EBS area. During the most recent complete five-year period (2000-2004), the EBS accounted for an average of about 83% of the BSAI catch.

Current regulations specify that the BSAI Pacific cod TAC will be allocated initially according to gear type as follows: the trawl fishery will be allocated 47%, the fixed gear (longline and pot) fishery will be allocated 51%, and the jig fishery will be allocated 2%; of the fixed gear allocation, the longline fishery will be allocated 80.3% (not counting catcher vessels less than 60 ft LOA), the pot fishery will be allocated 18.3% (not counting catcher vessels less than 60 ft. LOA), and fixed-gear catcher vessels less than 60 ft. LOA will be allocated 1.4%. Typically, as the harvest year progresses, it becomes apparent that one or more gear types will be unable to harvest their full allotment(s) by the end of the year. This is addressed by reallocating TAC between gear types in September of each year. Most often, such reallocations shift TAC from the trawl, jig, and sometimes pot components of the fishery to the longline catcher/processors. The longline catcher-processors typically receive 15,000-20,000 t per year through such transfers.

The catches shown in Tables 2.1b, 2.2b, 2.3b, and 2.4 include estimated discards. Discard rates of Pacific cod in the various EBS and AI target fisheries are shown for each year 1991-2002 in Table 2.5a and for each year 2003-2004 in Table 2.5b.

DATA

This section describes data used in the current assessment. It does not attempt to summarize all available data pertaining to Pacific cod in the BSAI.

Commercial Catch Data

Catch Biomass

Catches (which may not include discards) taken in the EBS for the period 1964-1980 are shown in Table 2.6a and catches (including estimated discards) taken in the EBS for the period 1981-2005 are shown in Table 2.6b. Catches in these tables are broken down by the three main gear types and intra-annual periods consisting of the months January-May, June-August, and September-December. This particular division, which was suggested by participants in the EBS fishery, is intended to reflect actual intra-annual differences in fleet operation (e.g., fishing operations during the spawning period may be different than at other times of year). In years for which estimates of the distribution by gear or period were not available, proxies based on other years' distributions were used.

Catch Size Composition

Fishery size compositions are presently available, by gear, for at least one gear type in every year from 1974 through the first part of 2005, with the exception of 1976. For ease of representation and analysis, length frequency data for Pacific cod can usefully be grouped according to the following set of 25 intervals or "bins," with the upper and lower boundaries shown in cm:

BinNumber:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
LowerBound:	9	12	15	18	21	24	27	30	33	36	39	42	45	50	55	60	65	70	75	80	85	90	95	100	105
UpperBound:	11	14	17	20	23	26	29	32	35	38	41	44	49	54	59	64	69	74	79	84	89	94	99	104	110

Total length sample sizes for each year, gear, and period are shown in Table 2.7. The collections of relative length frequencies are shown by year, period, and size bin for the trawl fishery in Tables 2.8a, 2.8b, and 2.8c; the longline fishery in Tables 2.9a, 2.9b, and 2.9c; and the pot fishery in Tables 2.10a and 2.10b.

Survey Data

EBS Shelf Bottom Trawl Survey

The relative size compositions from bottom trawl surveys of the EBS shelf conducted by the Alaska Fisheries Science Center since 1979 are shown in Table 2.11, using the same length bins defined above for the commercial catch size compositions. Information regarding the absolute numbers of fish measured at each length is available only for the years 1982-1987 and 1990-2005. For all other years, only relative numbers of measured fish are available. The total sample sizes (N) from the years 1982-1987 and 1990-2005 are shown below:

Year	N	Year	N	Year	N
1979	n/a	1988	n/a	1997	9169
1980	n/a	1989	n/a	1998	9583
1981	n/a	1990	5628	1999	11699
1982	10540	1991	7228	2000	12564
1983	13143	1992	9601	2001	19750
1984	12133	1993	10404	2002	12238
1985	16886	1994	13922	2003	12360
1986	15376	1995	9216	2004	10800
1987	10609	1996	9348	2005	11294

Following a decade-long hiatus in production ageing of Pacific cod, the Age and Growth Unit of the Alaska Fisheries Science Center began ageing samples of Pacific cod from the EBS shelf bottom trawl surveys a few years ago (Roberson 2001, Roberson et al. 2005). To date, the otolith collections from the 1996-2003 surveys have been read. The relative age compositions from these surveys are shown in Table 2.12. The number of fish aged for each of these years is shown below:

Year:	1996	1997	1998	1999	2000	2001	2002	2003
N:	252	719	635	860	864	950	947	1360

Estimates of total abundance (both in biomass and numbers of fish) obtained from the trawl surveys are shown in Table 2.13, together with the standard errors and upper and lower 95% confidence intervals (CI) for the biomass estimates. Survey results indicate that biomass increased steadily from 1978 through 1983, then remained relatively constant from 1983 through 1989. The highest biomass ever observed by the survey was the 1994 estimate of 1,368,109 t. Following the high observation in 1994, the survey biomass estimate declined steadily through 1998. The survey biomass estimates have remained in the 525,000-625,000 t range from 1997 through the present, except for 2001, when the estimate was 830,479 t. The 2005 estimate was 603,788 t.

In terms of numbers (as opposed to biomass), the record high was observed in 1979, when the population was estimated to include over 1.5 billion fish. The 1994 estimate of population numbers was the second highest on record. After the peak in 1994, numerical declines were observed through 1997, paralleling the biomass time trend. The survey estimate of population numbers remained in the 420-570 million fish range from 1997 through the present, except for 2001, when the estimate was 980 million fish. The 2005 estimate was 452,075,840 fish.

Both the biomass and numerical abundance estimates from the 2001 survey appear likely to be overestimates, given the magnitudes of the implied increases relative to the 2000 survey (57% and 104%, respectively) and the fact that the 2002-2005 estimates were much closer to the preceding estimates.

Another item of information collected annually by the EBS shelf bottom trawl survey is average bottom temperature. The annual temperature anomalies (annual temperature in degrees Celsius minus time series mean) are shown below:

Year	Temp.	Year	Temp.	Year	Temp.
1979	n/a	1988	-0.239	1997	0.170
1980	n/a	1989	0.352	1998	0.651
1981	n/a	1990	-0.246	1999	-1.832
1982	-0.467	1991	0.164	2000	-0.460
1983	0.417	1992	-0.720	2001	-0.057
1984	-0.304	1993	0.424	2002	0.638
1985	-0.265	1994	-0.714	2003	1.145
1986	-0.766	1995	-0.857	2004	0.736
1987	0.606	1996	0.807	2005	0.821

EBS Slope Bottom Trawl Survey
The Alaska Fisheries Science Center conducted bottom trawl surveys of the EBS slope in 2002 and 2004. The relative size compositions from these surveys are shown in Table 2.14, using the same length bins defined above for the commercial catch size compositions. A total of 468 fish were measured in the 2002 survey and a total of 531 fish were measured in the 2004 survey (note that these sample sizes are only about one-twentieth of the average sample size from the shelf survey). The biomass estimates and standard errors from the 2002 and 2004 surveys are shown below (all figures are in t):

Year	Biomass	Standard Error
2002	7511	1944
2004	5756	968

Aleutian Bottom Trawl Survey
Biomass estimates for the Aleutian Islands region were derived from U.S.-Japan cooperative bottom trawl surveys conducted during the summers of 1980, 1983, and 1986, and by U.S. bottom trawl surveys of the same area in 1991, 1994, 1997, 2000, 2002, and 2004. These surveys covered both the Aleutian management area (170 degrees east to 170 degrees west) and a portion of the Bering Sea management area ("Southern Bering Sea") not covered by the EBS shelf bottom trawl surveys. The time series of biomass estimates from both portions of the Aleutian survey area are shown together with their sum below (all figures are in t):

Year	Survey Type	Aleutian Mgmt. Area	Southern Bering Sea	Aleutian Survey Area
1980	U.S.-Japan	52,070	74,373	126,443
1983	U.S.-Japan	113,148	45,624	158,772
1986	U.S.-Japan	172,625	42,298	214,923
1991	U.S.	180,904	8,286	189,190
1994	U.S.	153,026	31,084	184,109
1997	U.S.	72,674	10,742	83,416
2000	U.S.	126,918	9,157	136,075
2002	U.S.	73,252	9,601	82,853
2004	U.S.	82,432	31,964	114,396

For many years, the assessments of Pacific cod in the BSAI used a weighted average formed from EBS and Aleutian survey biomass estimates to provide a conversion factor which was used to translate model projections of EBS catch and biomass into BSAI equivalents. Because the assessment model is configured to represent the portion of the Pacific cod population inhabiting the EBS survey area (as opposed to the more extensive EBS *management* area), the biomass estimates from the entire Aleutian survey area (as opposed to the less extensive Aleutian *management* area) were used to inflate model projections of EBS catch and biomass. Prior to the 2004 assessment, the weighted average was based on the sums of the biomass estimates from the EBS shelf and AI survey biomass time series.

However, in December of 2003 the SSC requested that alternative methods of estimating relative biomass between the EBS and AI be explored. Following a presentation of some possible alternatives, the SSC recommended that an approach based on a simple Kalman filter be used (SSC Minutes, October, 2004). Using the Kalman filter approach, the best estimate of the long-term average biomass distribution is 85% EBS and 15% AI, which, coincidentally is identical to the biomass distribution estimated by the former (weighted average) approach. Because the 83-112 net (with no roller gear) used in the EBS survey generally tends the bottom better than the polyethylene Noreastern net (with roller gear) used in the AI survey, this ratio should tend to err on the conservative side (that is, the AI survey would be expected to miss more fish than the EBS survey, so the true portion in the AI should be higher than the ratio of the AI to AI+EBS survey estimates).

Length at Age

Production ageing of Pacific cod at the Alaska Fisheries Science Center was curtailed in the early 1990s and did not resume for approximately ten years. During the intervening period, age data were used only sparingly in the BSAI Pacific cod assessment. By the time that the 2004 assessment was conducted, length-at-age data from the 1998-2003 surveys had become available. This year, length-at-age data from the 1996-1997 surveys are also available. The annual mean lengths (cm) at ages 1.5-12.5 are shown below (data were collected during summer; ages assume a January 1 birthdate; ages 13.5 and 14.5 are not shown because of small sample sizes):

Year	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5
1996	20.0	31.8	41.5	50.6	57.0	64.9	72.3	n/a	n/a	n/a	n/a	n/a
1997	17.7	32.2	42.2	51.4	59.7	64.5	72.4	77.0	85.3	90.8	92.0	n/a
1998	15.3	30.9	38.1	49.4	59.0	66.8	69.6	77.1	89.6	n/a	94.0	n/a
1999	15.6	29.5	40.3	46.2	56.5	65.1	70.5	77.5	76.8	n/a	88.0	n/a
2000	15.2	30.3	38.2	47.6	54.0	59.0	70.4	70.1	77.7	79.1	70.0	n/a
2001	17.9	31.3	36.6	48.2	55.5	61.5	65.1	74.1	74.4	70.0	87.1	91.0
2002	16.8	30.2	36.7	46.8	55.4	63.0	68.3	70.0	74.6	93.1	n/a	95.0
2003	18.1	29.8	40.9	48.3	56.5	65.2	70.5	74.7	81.5	78.0	78.6	n/a

The following sample sizes are associated with the above mean lengths at age:

Year	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5
1996	1	69	60	66	22	25	9	0	0	0	0	0
1997	94	92	109	125	120	110	38	21	5	3	2	0
1998	56	145	97	94	73	88	47	28	6	0	1	0
1999	84	167	195	162	105	77	44	17	8	0	1	0
2000	112	102	131	204	177	83	21	20	7	6	1	0
2001	173	161	159	135	127	119	43	15	7	4	5	1
2002	114	165	206	189	85	91	70	16	6	2	0	2
2003	193	222	205	198	206	129	114	68	17	1	4	0

The aggregate data from these eight surveys provide the following relationship between age and length and the amount of spread around that relationship:

Age:	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5
Mean Length:	17.6	29.9	39.2	48.8	57.7	65.0	71.3	77.4	82.5	84.8	89.0	95.0	86.7	89.0
St. Deviation:	3.5	4.0	4.6	4.7	5.9	6.2	7.2	8.7	9.7	11.8	10.7	4.0	14.5	n/a
N:	827	1123	1162	1173	915	722	386	185	56	16	14	3	3	1

The SSC has asked that the potential significance of sex-specific length at age be addressed (SSC minutes, December 2004). Figure 2.2 shows sex-specific schedules of mean length at age based on the 1996-2003 surveys data, together with 95% confidence intervals. The sex-specific means appear to be very close throughout most of the age range. Although the female curve is slightly higher than the male curve at older ages, the means for each sex fall within the confidence interval for the other sex at all ages except age 8.5.

Weight at Length

Weight measurements taken during summer bottom trawl surveys since 1975 yield the following data regarding average weights (in kg) at length, grouped according to size composition bin (as defined under "Catch Size Composition" above):

Bin:	1	2	3	4	5	6	7	8	9	10	11	12	13
Ave. Weight:	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.6	0.7	0.9	1.2
Bin:	14	15	16	17	18	19	20	21	22	23	24	25	
Ave. Weight:	1.6	2.2	2.9	3.5	4.6	5.6	7.0	8.4	10.1	11.8	11.0	15.0	

The SSC has asked that the potential significance of sex-specific weight at length be addressed (SSC minutes, December 2004). Figure 2.3 shows sex-specific schedules of mean weight at length based on the 1996-2003 surveys data, together with 95% confidence intervals. The sex-specific means appear to be very close throughout most of the length range. At longer lengths, the means may not overlap, but there is no obvious trend (i.e., males have higher average weight than females at some lengths but not at others) and the means for each sex typically fall within the confidence interval for the other sex.

The SSC has also asked that the potential significance of interannual variability in weight-at-length relationships and condition factor be addressed (SSC minutes, December 2004). For this purpose, a set of seven example years was chosen: 1975, 1980, 1985, 1990, 1995, 2000, and 2005. For each of these years, all the available weight-at-length data from the commercial fisheries were compiled (commercial fishery data were chosen rather than survey data because Pacific cod weights were not collected in all surveys and because the survey database extends back only to 1979, whereas the commercial fishery database includes some data collected before the 1976-1977 regime shift). The average month of collection (where January=1) ranged from 3.7 to 6.6, with the data from the three most recent years (1995, 2000, and 2005) tending to be collected somewhat earlier in the respective year than the data from the other years. By gear type, the data for 1975 and 1990 were collected predominantly from the trawl fishery, the data for 1990 were collected predominantly from the pot fishery, and the data for the remaining years were collected predominantly from the longline fishery.

The mean weights at each length are shown for each year in Figure 2.4 (to reduce the possibility of outliers resulting from small sample sizes, only those points representing the average of at least 5 data points are shown). For the most part, the mean weights at length appear very close for all years. Two possible exceptions are the data for 1975, which look like they may tend to give slightly higher mean weights at length than the other years, and the data for 1980, which look like they may tend in the opposite direction. However, 1975 and 1980 are also the two years with the smallest sample sizes (n=280 and n=1764, respectively, compared to an average n=2852 for the entire time series).

"Condition factor," conventionally defined as the ratio of weight to the cube of length, is commonly used to compare the health of individual fish of the same species (Fulton 1911, Ricker 1975). The average condition factor (across lengths) for each of the seven example years is plotted together with 95% confidence intervals in Figure 2.5. Because condition factor is a relative measure, the values in Figure 2.5 have been normalized by expressing each point as the ratio of the year-specific estimate to the estimate for the entire time series. Statistically speaking, the point estimates in Figure 2.5 are significantly different under any reasonable criterion. However, it should be emphasized that such a result would probably be expected, given that only one parameter is being estimated for each year and a total of approximately 20,000 points is used in the analysis. More important questions are, "How different are they?" and, "Would such differences be important to incorporate into the stock assessment?" It may be useful to pursue these questions further in future assessments, but for the time being it may be sufficient to note that there does not appear to be any obvious time trend to the points in Figure 2.5, and all but one of the points is within 5% of the long-term average.

Maturity at Length
From 1984 through 1994, the BSAI Pacific cod assessments used a maturity schedule based on a gonado-somatic index calculated from a sample of 1900 fish collected during the 1981 and 1982 survey seasons and described by Teshima (1985).

From 1995 through 2004, the BSAI Pacific cod assessments used a maturity schedule based on a sampling program conducted in 1993-1994, using commercial fishery observers. The data consisted of observers' visual determinations regarding the spawning condition of 2312 females taken in the EBS fishery. Of these 2312 females, 231 were smaller than 42 cm (the lower boundary of length bin 12). None of these sub-42 cm fish were mature. The observed proportions of mature fish in the remaining length bins, together with the numbers of fish sampled in those length bins, are shown below (bins are defined under "Catch Size Composition" above):

Bin number:	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Prop. mature:	0.03	0.05	0.14	0.19	0.28	0.53	0.69	0.82	0.89	0.94	0.94	0.91	0.89	1.00
Sample size:	39	122	226	313	295	300	320	177	103	70	50	35	19	12

Recently, Stark (2005) completed an in-depth histological study of Pacific cod maturity in both the BSAI and GOA. In the BSAI, 268 female fish were collected near Unimak Pass using pot gear during the months of January-March in 2003. Methods were the same as those used by Stark (2004). Oocytes within each ovary were classified into seven histological stages based on the criteria of Hunter et al. (1992) and Stark (2004). Fish with ovaries containing either hydrated oocytes or post-ovulatory follicles were classified as spawners. Specimens collected from the BSAI ranged in size from 35-106 cm. The smallest spawning female collected from the BSAI was 46 cm. Ovary weights were found to represent up to 30% of total body weight.

ANALYTIC APPROACH

Model Structure

Beginning with the 1993 SAFE report (Thompson and Methot 1993), a model using the SS1 assessment program (Methot 1986, 1990, 1998, 2000) and based largely on length-structured data has formed the primary analytical tool used to assess the EBS Pacific cod stock. SS1 is a program that uses the parameters of a set of equations governing the assumed dynamics of the stock (the "model parameters") as surrogates for the parameters of statistical distributions from which the data are assumed to be drawn (the "distribution parameters"), and varies the model parameters systematically in the direction of increasing likelihood until a maximum is reached. The overall likelihood is the product of the likelihoods for each of the model components. Each likelihood component is associated with a set of data assumed to be drawn from statistical distributions of the same general form (e.g., multinomial, lognormal, etc.). Typically, likelihood components are associated with data sets such as catch size (or age) composition, survey size (or age) composition, and survey biomass.

SS1 permits each data time series to be divided into multiple segments, resulting in a separate set of parameter estimates for each segment. In the base model for the EBS Pacific cod assessment, for example, the survey size composition and survey biomass time series have traditionally been split into pre-1982 and post-1981 segments to account for the effects of a change in the trawl survey gear that occurred in 1982. Also, to account for possible differences in selectivity between the mostly foreign (also joint venture) and mostly domestic fisheries, the fishery size composition time series in the base model for EBS Pacific cod has traditionally been split into pre-1989 and post-1988 segments.

The base model for EBS Pacific cod remained completely unchanged from 1997 to 2001. A minor modification of the base model was suggested by the SSC in 2001, namely, that consideration be given to dividing the domestic era into pre-2000 and post-1999 segments. This modification was tested in the 2002 assessment (Thompson and Dorn 2002), where it was found to result in a statistically significant improvement in the model's ability to fit the data. In last year's assessment, further modifications were made to the base model. The revised model included a set of selectivity parameters for the EBS slope bottom trawl survey and added new likelihood components for the age composition and length-at-age data from the 1998-2003 EBS shelf bottom trawl surveys and the size composition and biomass data from the 2002 and 2004 EBS slope bottom trawl surveys. Incorporation of age data and slope survey data had been suggested by the SSC (SSC minutes, December 2003).

However, after so many years of application, the SS1 architecture has by this time become somewhat dated. Three features can be identified as no longer state-of-the-art: First, SS1 uses a finite difference algorithm to minimize the objective function, whereas most state-of-the-art assessments use automatic differentiation (e.g., Greiwank and Corliss 1991), for example, as found in the ADMB modeling package (Fournier 2005). Benchmark tests have tended to indicate that automatic differentiation is a superior algorithm. Second, SS1 attempts to estimate all parameters simultaneously, whereas models programmed in ADMB can include "phased" estimation, where attention is focused initially on only a subset of parameters, and additional parameters are added to the "active" list with each subsequent phase, until finally all parameters are active in the final phase. By attempting to estimate all parameters simultaneously, SS1 is more likely to get trapped in a local minimum. Third, SS1 does not include utilities for estimating confidence intervals or posterior distributions of derived quantities (e.g, spawning biomass), whereas models programmed in ADMB can easily be tailored to estimate such confidence intervals or distributions so long as the estimated Hessian matrix is positive definite.

Therefore, SS1 is being replaced by a new program, SS2, which, for the most part, is simply SS1 rewritten in ADMB. A full description of SS2, including the equations used to model population dynamics and the various observation processes, is given by Methot (2005a). This year's Pacific cod assessment includes three alternative models. Model 1 was configured under SS1, while Models 2 and 3 were configured under SS2 (see "Model Evaluation" below). The structure of Model 1 configured under SS1 is identical to that described in last year's assessment (Thompson and Dorn 2004).

Although the main difference between SS1 and SS2 is the use of ADMB by SS2, there are a number of other technical differences. The most important of these, and how they were addressed in the present assessment, are described in the following paragraphs.

Minimum and Maximum Age

SS1 allowed the user to specify the minimum age in the model, whereas SS2 automatically sets the minimum age equal to zero. This does not mean, however, that the data have to include age 0 fish; it simply means that SS2 always begins calculating the age structure of the population at age 0. Moreover, the SS2 user can still specify a "summary age range" for use in reporting output, where the minimum age is completely flexible. Another difference between SS1 and SS2 is that users of SS1 were encouraged to set a fairly low age for the boundary of the "plus" group, with the age structure of the plus group governed by a user-specified "old age discount" parameter, whereas users of SS2 are encouraged to set a fairly high age for the boundary of the plus group, so that the age structure of the plus group essentially does not matter (again, setting a high maximum age does not mean that the data must include all ages up to that maximum, it simply means that SS2 will calculate the age structure of the population up to that maximum). In SS1, maximum age for the Pacific cod model has always been set equal to 12, and this assumption is retained for the SS1 model included in the present assessment. For the models developed under SS2 in this year's assessment, maximum age is set equal to 20.

Initial Numbers at Age

SS1 provided users with the choice of setting the numbers-at-age vector in the initial year equal to the equilibrium numbers-at-age vector associated with user-specified levels of catch and recruitment, or estimating each element of the numbers-at-age vector in the initial year as a free parameter. Previous

EBS Pacific cod assessment models have always used the second option, where the initial year was set equal to 1978. However, SS2 requires use of the first option. Use of an equilibrium initial numbers-at-age vector necessitates a number of modifications to the EBS Pacific cod assessment model. This is because previous assessments of this stock, as well as conventional wisdom, have consistently indicated that one or more exceptionally large year classes spawned in or around 1977 were present in the population in 1978, but most other age groups were at very low levels of abundance in that year, meaning that the assumption of initial equilibrium would likely be very misleading (i.e, it would either cause the large year classes to be drastically under-estimated, or the other year classes to be drastically over-estimated).

It is clear that the assumption of initial equilibrium requires an earlier initial year for the assessment model. Annual catch data are available as far back as 1964. Setting the initial year equal to 1964 would give the model plenty of time to generate a reasonable age structure by the time the large year classes of the mid-to-late 1970s were spawned. However, setting the initial year any earlier than 1977 requires estimating one or more year classes prior to the well-documented 1977 environmental regime shift (e.g., Hare and Mantua 2000), which should have a lower median value than year classes spawned after the 1977 regime shift. Establishing different pre-1977 and post-1976 medians is easily accomplished in SS2 by creating a regime shift "dummy variable" for each year in the time series and estimating a link between median recruitment and the dummy variable. However, this creates another problem, because the parameter governing the amount of stochastic variability in recruitment (σ_R) cannot be linked to the dummy variable. This means that the mean recruitment deviation for each portion of the time series (pre-1977 and post-1976) will not necessarily equal zero, even though SS2 forces the mean recruitment deviation for the overall time series to equal zero. This, in turn, means that the estimates of the pre- and post-regime shift medians will be confounded with the estimate of σ_R.

To resolve the problem of confounding between the estimates of the pre-1977 and post-1976 recruitment medians with the estimate of σ_R, the following iterative algorithm was used to implement an environmental regime shift in SS2.

1. Candidate values for the pre-1977 log-scale mean and σ_R were chosen.
2. SS2 was allowed to estimate the post-1976 log-scale mean and the recruitment deviations for the entire time series (deviations are expressed as the difference between the logarithm of annual recruitment at age 0 and the log-scale mean for the respective environmental regime), conditional on the candidate values for the pre-1977 log-scale mean and σ_R.
3. The mean of the estimated pre-1977 recruitment deviations and the standard deviation of the entire time series of recruitment deviations were computed.
4. If the absolute value of the mean computed in Step 3 was less than 0.005 and the standard deviation computed in Step 3 was equal to σ_R with three significant digits, the candidate values were determined to be the final estimates. If either of these conditions did not hold, the candidate value for the pre-1977 log-scale mean was set equal to the old value plus the mean computed in Step 3, the candidate value for σ_R was set equal to the standard deviation computed in Step 3, and the process returned to Step 2.

The above algorithm was tested many times under different initial candidate values and consistently returned the same final estimates.

Selectivity
As alluded to above, a total of fourteen selectivity curves are specified by the EBS Pacific cod model. Three curves apiece are specified for the January-May trawl fishery, the June-December trawl fishery, and the longline fishery, corresponding to the time periods 1964-1988, 1989-1999, and 2000-2005. Two curves are specified for the pot fishery, corresponding to the time periods 1989-1999 and 2000-2005

(there was no significant pot fishery for Pacific cod prior to 1989). Two curves are specified for the EBS shelf bottom trawl survey, corresponding to the time periods 1979-1981 and 1982-2005. A single curve is specified for the EBS slope bottom trawl survey.

Although SS2 includes several options for specifying the functional form of the selectivity curve, the most flexible and commonly used option involves a pair of scaled logistic curves joined by a horizontal linear segment. The first (ascending) logistic curve begins at the minimum length specified in the data file (9 cm in the case of the EBS Pacific cod model), where the selectivity is less than 1.0, and ends at some intermediate length, where selectivity is exactly 1.0. A horizontal linear segment extends from the right-hand end of the first logistic to the left-hand end of the second logistic. Selectivity equals 1.0 throughout this linear segment. The second (descending) logistic curve begins at the end of the horizontal linear segment, where selectivity is still exactly 1.0, and ends at the maximum length specified in the data file (110 cm in the case of the EBS Pacific cod model), where the selectivity is less than 1.0. This selectivity function is similar to the primary selectivity function used in SS1, except that the function used in SS1 omits the horizontal linear segment that joins the two logistic curves in the SS2 version of the function (i.e., selectivity in the SS1 version equals 1.0 at a single point only, whereas the SS2 version allows selectivity to equal 1.0 throughout a range of values).

Eight parameters are used to define the SS2 selectivity function: the size at which selectivity first reaches a value of 1.0 (*peak location*), the selectivity at the minimum length represented in the data ($S(Lmin)$), the logit transform of the size corresponding to the inflection of the ascending logistic curve (logit(*infl1*)), the relative slope of the ascending logistic curve (*slope1*), the logit transform of the size corresponding to the inflection of the descending logistic curve (logit(*infl2*)), the relative slope of the descending logistic curve (*slope2*), the logit transform of the selectivity at the maximum length represented in the data (logit($S(Lmax)$)), and the width of the length range at which selectivity equals 1 (*peak width*). The parameters are similar in the SS1 version of the selectivity function, except that *peak width* is implicitly set equal to zero.

Prior Distributions
A potentially major difference between SS1 and SS2 is that SS2 is explicitly cast in a Bayesian framework, with specification of a prior distribution required for each parameter. Of course, a noninformative prior can be chosen for any or all parameters if so desired. However, use of informative priors is probably appropriate for many of the parameters in the EBS Pacific cod model, because both the Plan Team and the SSC have indicated in the past that certain values, or ranges of values, of various parameters are either relatively likely or unlikely. For example, the SSC has indicated that a natural mortality rate of 0.37 is likely close to the true value, at least for the GOA stock of Pacific cod (SSC minutes, December 1994). As another example, the Plan Team has expressed concern that previous assessments' estimates of large-fish selectivity in the EBS shelf bottom trawl survey may be too low (Plan Team minutes, November 2004). By utilizing a Bayesian framework, SS2 provides a logical means of integrating perspectives such as these into the stock assessment model. The specific priors used in this assessment are described under "Parameters Estimated Conditionally" below.

Parameters Estimated Independently

Natural Mortality
In the 1993 BSAI Pacific cod assessment (Thompson and Methot 1993), the natural mortality rate M was estimated using SS1 at a value of 0.37. All subsequent assessments of the BSAI Pacific cod stock have used this value for M (as have all subsequent assessments of the GOA Pacific cod stock, with one exception). Other published estimates of M for Pacific cod are shown below:

Area	Author	Year	Value
Eastern Bering Sea	Low	1974	0.30-0.45
	Wespestad et al.	1982	0.70
	Bakkala and Wespestad	1985	0.45
	Thompson and Shimada	1990	0.29
	Thompson and Methot	1993	0.37
Gulf of Alaska	Thompson and Zenger	1993	0.27
	Thompson and Zenger	1995	0.50
British Columbia	Ketchen	1964	0.83-0.99
	Fournier	1983	0.65

As the above table indicates, the natural mortality rate for Pacific cod is either highly variable by time or area or it is very hard to estimate. In Models 1 and 2, M is fixed at the traditional value of 0.37. In Model 3, M is estimated internally.

Trawl Survey Catchability

The base model used in all previous BSAI Pacific cod assessments has fixed the catchability coefficient (Q) for the EBS shelf bottom trawl survey independently of other parameters at a value of 1.0. Somerton (2004) has shown that Q for Pacific cod in the EBS is very unlikely to be greater than 1.0.

Following Wilderbuer and Sample (2003), the survey catchability coefficient in last year's BSAI Pacific cod assessment was partitioned proportionately between the EBS shelf and slope, with the sum of the coefficients fixed at 1.0. Using a Kalman filter analysis similar to that described by Thompson and Dorn (2004), the best estimate of the long-term average biomass distribution between the EBS shelf and slope was found to be 0.992 shelf and 0.008 slope, and the shelf and slope survey catchability coefficients were set accordingly.

In Models 1 and 2, the shelf and slope catchabilities are set at the values used in last year's assessment. In Model 3, the values of these two catchabilities are estimated internally.

Weight at Length

Parameters governing the allometric relationship between weight and length were estimated in a previous assessment by log-log regression from the available data (see "Data" above, with weights given in kg and lengths in cm), giving a multiplicative constant of 4.36×10^{-6} and an exponent of 3.242.

Variability in Estimated Age

In the configuration adopted in last year's assessment, SS1 used estimates of the schedule of percent agreement ("PA") between age readers. In last year's assessment, weighted least squares regression was used to fit an exponential relationship to the available data (total sample size = 2,256), giving the following schedule:

Age:	1	2	3	4	5	6	7	8	9	10	11	12
Mean PA:	0.929	0.743	0.613	0.556	0.466	0.400	0.356	0.288	0.333	0.333	0.250	n/a
Std. Error:	0.014	0.024	0.025	0.025	0.026	0.032	0.044	0.059	0.122	0.157	0.217	n/a
Regression:	0.900	0.767	0.654	0.557	0.475	0.405	0.345	0.294	0.250	0.213	0.182	0.155

In Model 1, the above schedule is retained.

SS2, on the other hand, uses standard deviation of estimated age instead of percent agreement. Weighted least squares regression was used to estimate a proportional relationship between standard deviation and age. The resulting estimate of the proportionality constant was 0.0907 (i.e, the standard deviation of estimated age was modeled as 0.0907 × age). This relationship was used in Models 2 and 3.

Maturity at Length

As in previous assessments of EBS Pacific cod, the present assessment uses a single (i.e., time-invariant), length-based maturity schedule. Although the maturity schedule is constant within a given assessment, the values of the parameters describing the maturity schedule have changed over time. The history of maturity schedules used previously or now available for use in the BSAI Pacific cod assessment may be summarized as follows, where the length at 50% maturity (*L50*) and slope of the linearized logistic equation (*A*) are used to characterize each schedule:

1) From 1984 through 1994, the maturity schedule was based on gonado-somatic index values from the 1981-1982 surveys, with *L50* and *A* values of 61 cm and -0.248, respectively (Teshima 1985).
2) From 1995 through 2004, the maturity schedule was based on macroscopic observations ("scans") from the 1994 commercial fishery, with *L50* and *A* values of 67 cm and -0.142, respectively (Thompson 1995).
3) For this year's assessment, another possible candidate is Stark's (2005) maturity schedule, based on histological samples from pot surveys conducted during January-March of 2003, with *L50* and *A* values of 58 cm and -0.132, respectively.

To provide some context for the above schedules, it may be helpful to consider alternative estimates. Two categories of alternative estimates are those derived from "rules of thumb" based on life history parameters and those derived from biological samples. The method suggested by Roff (1984), based on the Brody growth coefficient *K* and the natural mortality rate, falls within the "rules of thumb" category. The available length-at-age data (see "Length at Age" under "Data" above) suggest a *K* value of about 0.12 (based on maximum likelihood). Using this estimate of *K* and the conventional Pacific cod *M* value of 0.37, Roff's method implies an age at maturity of about 5.7 years, corresponding to a length of about 59 cm (based on linear interpolation). Royce (1972) suggested another rule of thumb, namely, that the age at maturity should typically be less than one-third of the maximum age observed in the stock. The maximum age observed in the 1996-2003 surveys was 14 years, which, using Royce's method, would imply an age at maturity somewhere less than 4.7 years, corresponding to a length of about 51 cm (based on linear interpolation). In the category of estimates derived from biological samples, Rovnina et al. (1997) estimated *L50* at 55-60 cm for Pacific cod in the Sea of Okhotsk, Welch and Foucher (1988) estimated *L50* at 45-55 cm for Pacific cod in British Columbia, and Hattori et al. (1992) estimated that 50% of Pacific cod in the Sea of Japan were mature by age 4 which, for BSAI Pacific cod, corresponds to a length of about 44 cm (based on linear interpolation). All of these alternative estimates are closer to Stark's (2005) estimate of *L50* than the estimate used in recent assessments.

In addition to the above, the following reasons support use of Stark's (2005) maturity-at-length schedule (the "new schedule"):

1) The new schedule is based on a published methodology (Stark 2004) that is the source of the maturity schedules used in several other BSAI and GOA groundfish assessments (BSAI flathead sole, GOA flathead sole, GOA northern rock sole, GOA southern rock sole).
2) The author of the new maturity schedule has extensive experience in both macroscopic and histological estimation of Pacific cod maturity and is convinced that the histological methods are more accurate.
3) The method used to determine the maturity schedule used in recent Pacific cod assessments is subject to factors that might cause the resulting *L50* value to be biased high, whereas the method used to determine the new schedule is not subject to these factors, as described below.

Ova that contain yolk (mature ova) appear transparent, in contrast to the opaque appearance of ova that do not contain yolk. The success of macroscopic maturity classification systems depends in part on the ability of observers to distinguish transparent ova from opaque ova. This distinction can be difficult to make, because the ova are not observed directly, but through the ovary wall. The difficulty is greater for smaller fish, and can bias classifications of smaller fish in favor of immaturity. The reason for this is that, as fish grow, the number of ova contained in each ovary increases more than proportionally, which in turn causes greater distention of the ovary wall when yolk accumulates in the ova. Greater distention results in greater transparency of the ovary wall, which in turn increases observers' ability to identify transparent ova through the ovary wall. Conversely, it is harder for observers to detect mature ova in smaller fish, because the ovary wall is typically less distended than in large fish, even when the ova are mature. For the same reason (disproportionately less stretching of the ovary wall in small fish), macroscopic observation of small fish that have already spawned during the year may result in an incorrect classification of "developing" or "immature" because it is difficult to detect the presence of disintegrating ova (a criterion used to distinguish "spent" ovaries) through the ovary wall in such fish.

In contrast, histological maturity classifications are not subject to these biases because the maturity classifications are based on a comprehensive microscopic assessment of each ovum and associated structures, such as post ovulatory follicles, contained within each ovary section. The examinations are conducted under controlled laboratory conditions. The probability of detecting yolk within an ovary is very high because all ovary slide sections are stained with eosin dye which attaches to any yolk protein present, giving it a distinctive pink coloration.

Parameters Estimated Conditionally

With a few exceptions, Models 1, 2, and 3 estimate similar parameters, although the number of parameters of a given type estimated by the three models may differ in some cases due to the fact that Model 1 sets the initial year at 1978 while Models 2 and 3 set the initial year at 1964. The parameters that all three models attempt to estimate internally consist of the following:

1. mean length at age 1.5, mean length at age 12, Brody growth coefficient K
2. log-scale mean recruitment for the post-1976 environmental regime
3. annual recruitments (Model 1) or annual recruitment deviations (Models 2 and 3)
4. selectivity parameters (7 for Model 1, 8 for Models 2 and 3) for each of 14 selectivity curves
5. initial fishing mortality (initial year = 1978 for Model 1, 1964 for Models 2 and 3)
6. year-, gear-, and season-specific fishing mortality rates

It should be noted that the fishing mortality rates in (6) are somewhat different from the other parameters in that their values are determined exactly given the values of the other parameters and the input catch data, which are assumed to be true values rather than estimates.

In addition to the parameters estimated internally by all three models, the following parameters are estimated by some subset of the three models:

1. Model 1 estimates each element of the initial numbers-at-age vector.
2. Models 2 and 3 estimate the log-scale mean recruitment for the pre-1977 environmental regime and the standard deviation of the recruitment deviations (though not quite internally, but rather through an iterative process described under "Model Structure" above).
3. Model 3 estimates the natural mortality rate M, the logarithm of the median shelf bottom trawl survey catchability coefficient $Qmed$, the logarithm of the slope bottom trawl survey catchability coefficient, and a link between annual Q and bottom temperature of the form $Q_y=\exp(\ln(Qmed)+\theta\times T_y)$, where Q_y is catchability in year y, T_y is the temperature anomaly in year y, and θ is the environmental link parameter.

In the case of Model 1, the estimator used is the peak of the logarithm of the likelihood function (see below). In the cases of Models 2 and 3, the estimator used is the mode of the logarithm of the joint posterior distribution, which is in turn calculated as the sum of the logarithms of the parameter-specific prior distributions (see below) and the logarithm of the likelihood function.

Prior Distributions
For the two models developed under SS2 in this year's assessment, the informative prior distributions described in the following paragraphs were specified (all distributions are normal):

Parameters with priors based on a specified coefficient of variation (CV)
Initial fishing mortality: The mean was set at 0.1, reflecting the conventional wisdom that the stock was lightly exploited during the 1960s. The standard deviation was set at 0.03, corresponding to a CV of 30%.

Selectivity parameter *S*(*Lmin*): For the commercial fisheries, this was not an estimated parameter, but was set at a fixed value of 0.001. This choice was based on the fact that almost no fish in the sub-18 cm range are taken in the commercial fisheries and because preliminary model runs invariably resulted in this parameter being bound at whatever minimum value was specified. For the surveys, the prior distribution was assigned a mean of 0.1 and a standard deviation of 0.03, corresponding to a 30% CV. In contrast to the commercial fisheries, 10% of the average shelf bottom trawl survey size composition (based on the most recent six years) has consisted of fish smaller than 18 cm.

Selectivity parameters *slope1* and *slope2*: These two parameters had identical priors, with the mean set at 0.2 and the standard deviation set at 0.06, corresponding to a 30% CV. The choice of mean was based on a subjective examination of the shape of the selectivity curve under different values of these parameters.

Selectivity parameter *peak width*: The mean was set at 10 and the standard deviation was set at 3, corresponding to a 30% CV. The choice of mean was based on a subjective examination of the shape of the selectivity curve under different values of this parameter, in addition to results from preliminary model runs which indicated that values much higher than 10 tended to cause the model to get "stuck."

Log median shelf survey catchability ln(*Qmed*): Model 3 treats median ln(*Qmed*) as a free parameter with a prior distribution (Model 3 also estimates a link between annual catchability and bottom temperature). This prior distribution was assigned a mean of -0.29 and a standard deviation of 0.05, corresponding to a lognormal prior for *Qmed* with a median of 0.75 and CV of 5%. The choices of mean and standard deviation for this prior distribution were difficult ones. In previous assessments, *Qmed* has always been fixed at a value of 1.0 (this was modified just slightly to a value of 0.992 in last year's assessment to accommodate the slope trawl survey biomass estimates, but for the purpose of simplifying the present discussion this value will be rounded to 1.0), which equates to a log value of 0. One natural way to convert a fixed constant into a free parameter with a normal prior is to treat the former fixed value as the mean of the new prior distribution and set a reasonable value for the standard deviation. However, this is not the only logical option. In the case of ln(*Qmed*) for EBS Pacific cod, for example, a value of 0 was used in last year's assessment not only because it was *consistent* with the results of Somerton (2004), but because it was the *upper limit* implied by those results (i.e., the results showed that it is very unlikely for the true value of ln(*Qmed*) to be positive). If the former fixed value of 0 is viewed as an upper limit, it does not make sense to treat it as the mean of the new prior. Rather, the mean and standard deviation of the new prior distribution should be set so that exceeding the upper limit is highly unlikely. The choice of -0.29 as the mean for the prior distribution was a subjective one. The choice of 0.05 for the standard deviation was pragmatic. A standard deviation of 0.05 probably underestimates the true uncertainty that ought to be associated with this prior distribution. However, preliminary model runs with higher values for the standard deviation inevitably resulted in point estimates for *Qmed* that were much higher than 1.0 (often in the neighborhood of 2.0), which cannot presently be reconciled with the results of Somerton (2004).

Natural mortality *M*: As with ln(*Qmed*), Model 2 fixes *M* at the value used in last year's assessment (0.37), while Model 3 treats it as a free parameter with a prior distribution. The prior distribution was assigned a mean of 0.37 and a standard deviation of 0.019, corresponding to a CV of 5%. Similar to the situation with ln(*Qmed*), the choice of 0.019 for the standard deviation was a pragmatic one. Although it probably underestimates the true uncertainty that ought to be associated with this prior distribution, preliminary model runs with higher values for the standard deviation inevitably resulted in point estimates for *M* that were much lower than 0.37 (often in the neighborhood of 0.20), which are so far from the traditionally accepted value that it does not seem wise to accept them without further investigation. Furthermore, higher values of the standard deviation for *M* tended to push the point estimates of *Qmed* to very high values that cannot be presently be reconciled with the results of Somerton (2004).

Parameters with priors based on one or both endpoints of the 98% confidence interval
Selectivity parameters logit(*infl1*) and logit(*infl2*): These two parameters had identical priors, with the mean set at 0 and the standard deviation set at 0.944. The mean corresponds to an inflection point located midway between *Lmin* and *peak location*, in the case of *infl1*, or between *peak location* and *Lmax*, in the case of *infl2*. The mean and standard deviation together imply a 98% confidence interval extending from 10% to 90% of the difference between *Lmin* and *peak location*, in the case of *infl1*, or between *peak location* and *Lmax*, in the case of *infl2*. The choice of mean was based on a subjective examination of the shape of the selectivity curve under different values of these parameters.

Selectivity parameter logit(*S*(*Lmax*)): The mean was set at 2.197 and the standard deviation was set at 0.944. The mean corresponds to a selectivity of 0.9 at *Lmax*. The mean and standard deviation together imply a 1% chance of selectivity at *Lmax* being less than 0.5. These parameter values were chosen in part to reflect the Plan Team's belief that selectivity of large fish in the bottom trawl survey should be fairly high.

Parameters with priors based on the data
Length at age parameters: Mean values for length at age 1.5, length at age 12, and the Brody growth coefficient *K* were set at 17.3, 92.1, and 0.12, respectively, corresponding to the maximum likelihood estimates obtained from the data collected during the 1996-2003 EBS shelf bottom trawl surveys. The standard deviations for these parameters were set at 0.067, 0.969, and 0.004, respectively, corresponding to the values associated with the inverted Hessian matrix obtained in the process of estimating the means.

Selectivity parameter *peak location*: The mean and standard deviation were set individually for each selectivity curve by identifying the length associated with the maximum frequency in each length frequency record, then computing the mean and standard deviation for each respective gear type and portion of the time series. This was done in order to give the model a reasonable starting value and place reasonable constraints on *peak location*, a parameter which is typically very difficult to estimate. The SS2 User Manual suggests that this parameter "should be an integer and should be at bin boundary and not estimated," but it also suggests that recent improvements to the code "may allow estimation" (Methot 2005b). Extensive testing during preliminary runs of the EBS Pacific cod model revealed that the value of this parameter can be quite important in determining model results and that free estimation (with a reasonably strong prior) was much more likely to find an optimal value than profiling manually over the range of possible integer values, especially considering the practical difficulty of manually tuning 14 parameters (one *peak location* for each selectivity curve) at the same time. The resulting means (cm) and standard deviations (cm) for *peak location* in each of the 14 selectivity curves were as follow:

Fishery/Survey	Years	Mean	Std. Dev.
Jan-May Trawl	1964-1988	62.6	8.57
Jan-May Trawl	1989-1999	59.2	10.80
Jan-May Trawl	2000-2005	67.1	12.90
Jul-Dec Trawl	1964-1988	63.4	8.47
Jul-Dec Trawl	1989-1999	66.4	10.50
Jul-Dec Trawl	2000-2005	60.0	9.83
Longline	1964-1988	63.0	6.31
Longline	1989-1999	62.5	4.55
Longline	2000-2005	59.0	3.45
Pot	1989-1999	65.2	4.71
Pot	2000-2005	61.7	3.10
Shelf Survey	1979-1981	41.7	6.94
Shelf Survey	1982-2005	36.8	11.90
Slope Survey	2002-2004	55.1	5.00

Likelihood Components

Likelihood components included in all three models are of four types: size composition, age composition, survey biomass, and mean size at age. There are six size composition components in the likelihood: one each for the January-May trawl fishery, the June-December trawl fishery, the longline fishery, the pot fishery, the shelf survey, and the slope survey. There is only one age composition component and one size-at-age component in the likelihood, because all age data currently come from the shelf survey. There are two survey biomass components in the likelihood: one for the shelf survey and one for the slope survey. In addition to the above, Models 2 and 3 include a recruitment deviations component.

Both SS1 and SS2 allow the user to specify "emphasis" factors that determine which components receive the greatest attention during the parameter estimation process. As in previous assessments, each component in each model was given an emphasis of 1.0 in the present assessment.

Use of Size Composition Data in Parameter Estimation
Size composition data are assumed to be drawn from a multinomial distribution specific to a particular year, gear/fishery, and time period within the year. In the parameter estimation process, SS1 and SS2 weight a given size composition observation (i.e., the size frequency distribution observed in a given year, gear/fishery, and period) according to the emphasis associated with the respective likelihood component and the sample size specified for the multinomial distribution from which the data are assumed to be drawn. In developing the model upon which SS1 was originally based, Fournier and Archibald (1982) suggested truncating the multinomial sample size at a value of 400 in order to compensate for contingencies which cause the sampling process to depart from the process that gives rise to the multinomial distribution. As in previous assessments, the present assessment uses a multinomial sample size equal to the square root of the true length sample size, rather than the true length sample size itself. Given the true length sample sizes observed in the present assessment, this procedure tends to give values somewhat below 400 while still providing the SS1 and SS2 programs with usable information regarding the appropriate effort to devote to fitting individual length samples. Multinomial length sample sizes derived by this procedure for the commercial fishery size compositions are shown in Table 2.15. In the case of EBS shelf bottom trawl survey size composition data, the square root assumption was also used, except that it was necessary to assume a true length sample size for the years 1979-1981 and 1988-1989, years for which such measures are unavailable (see "Trawl Survey Data" above). For those years, a true length sample size of 10,000 fish was assumed (giving a multinomial sample size of 100), which approximates the average of the 10 known true length sample sizes from the years 1986-1997. For the years 1982-1987 and 1990-2005, the square roots (sqrt) of the true survey length sample sizes are shown below:

Year	sqrt(N)	Year	sqrt(N)	Year	sqrt(N)
1979	n/a	1988	n/a	1997	96
1980	n/a	1989	n/a	1998	98
1981	n/a	1990	75	1999	108
1982	103	1991	85	2000	112
1983	115	1992	98	2001	141
1984	110	1993	102	2002	111
1985	130	1994	118	2003	111
1986	124	1995	96	2004	104
1987	103	1996	97	2005	106

For the 2002 and 2004 EBS slope bottom trawl surveys, the true length sample sizes and square roots are shown below:

Year:	2002	2004
True length sample size:	468	531
sqrt(N):	22	23

Use of Age Composition Data in Parameter Estimation

Like the size composition data, the age composition data are assumed to be drawn from a multinomial distribution specific to a particular year, gear/fishery (in this case, the EBS shelf bottom trawl survey), and time period within the year (in this case, the June-August period). However, selection of an appropriate input sample size is more complicated for age composition data than for length composition data, because age composition data are generated not only from the set of otolith readings but from the estimated size composition as well. Therefore, even if a square root transformation is appropriate for size composition data, taking the square root of the number of otoliths read may underestimate the weight that should be given to the age composition data. Last year's assessment introduced a method for setting an input sample size appropriate to age composition, a method which is retained in the present assessment. The steps are as follow:

1) The proportions of age at length are assumed to be approximately multivariate normally distributed, with a variance-covariance matrix determined by the matrix of proportions and the number of otoliths actually read at each length. A set of 10,000 random age-length keys was then simulated.
2) Survey numbers at each length are assumed to be approximately lognormally distributed with a mean equal to the point estimate and for that length and a constant (across lengths) coefficient of variation (CV) equal to the amount that sets the sum of the variances in numbers at length equal to the variance of the survey estimate of population size. A set 10,000 of random numbers-at-length distributions was then simulated.
3) For each combination of randomly simulated age-key and numbers-at-length distribution, an effective sample size was computed.
4) The "true" input sample size was set equal to the harmonic mean of the distribution of randomly simulated effective sample sizes, based on the asymptotic equivalence of these two quantities. The following table was thereby obtained for the age composition data (the last row shows the values used as "true" input sample sizes):

Year	1996	1997	1998	1999	2000	2001	2002	2003
Number of fish aged:	252	719	635	860	864	950	947	1360
Square root of number of fish aged:	16	27	25	29	29	31	31	37
CV of numbers at length:	0.96	1.08	0.55	0.60	0.72	0.63	0.65	0.87
Harmonic mean effective sample size:	40	50	97	130	102	108	109	76

Note that this procedure gives an input sample size larger than would be achieved simply by taking the square root of the number of fish aged (third row in the above table). This reflects the added precision achieved by use of both age-at-length and numbers-at-length data in constructing a numbers-at-age estimate. To avoid double counting of the same data, all three models ignore length composition data from the 1996-2003 EBS shelf bottom trawl surveys.

It may be noted that all but one of the harmonic mean effective sample sizes computed above is smaller than the sample sizes obtained for the corresponding length compositions using the "square root method" in the preceding subsection, suggesting that the two methods of computing sample sizes are not entirely consistent. This is not surprising, given that the square root method was adopted only as a simple approximation in the first place, but it does suggest a need for further work in this area.

Use of Size-at-Age Data in Parameter Estimation
Each size at age datum is assumed to be drawn from a normal distribution specific for that age and year. The model's estimate of mean size at age serves as the mean for that year's distribution, and the standard deviation is inversely proportional to the sample size (Methot 2000, Methot 2005a).

Use of Survey Biomass Data in Parameter Estimation
Each year's survey biomass datum is assumed to be drawn from a lognormal distribution specific to that year. The model's estimate of survey biomass in a given year serves as the geometric mean for that year's lognormal distribution, and the ratio of the survey biomass datum's standard error to the survey biomass datum itself serves as the distribution's coefficient of variation.

The EBS shelf bottom trawl survey biomass estimates are used in both models; the EBS slope bottom trawl survey biomass estimates are used only in Models 2 and 3.

Use of Recruitment Deviation "Data" in Parameter Estimation
The recruitment deviations likelihood component is different from traditional likelihoods because it does not involve "data" in the same sense that traditional likelihoods do. Instead, the log-scale recruitment deviation plays the role of the datum and the log-scale recruitment mean and σ_R play the role of the parameters in a normal distribution, but, of course, all of these are treated as parameters by SS2.

MODEL EVALUATION

As described in the preceding section, three alternative models are evaluated in the present assessment. Model 1 is identical to the SS1 model used in the 2004 assessment, where the natural mortality rate M and the shelf survey catchability coefficient Q were fixed at values of 0.37 and 0.992, respectively. Model 2 is developed under SS2 and differs from Model 1 in several respects, such as use of an earlier initial year and use of prior distributions for many model parameters, but retains Model 1's assumptions regarding the values of M and Q. Model 3 is also developed under SS2 and is identical to Model 2, except that the value of M is estimated rather than fixed, and Q is estimated as a function of bottom temperature.

Evaluation Criteria

In previous BSAI Pacific cod assessments, evaluation criteria have typically focused on effective sample sizes of the size composition data (and, more recently, the age composition data), the root mean squared error (RMSE) of the fit to the survey biomass data, and the overall reasonableness of the parameter values. These criteria are retained in the present assessment, not so much to determine which one of the three models is "best," but as a check to see whether any of the three can reasonably be rejected. Given that a model passes these tests, two additional evaluation criteria are as follow:

1. Do the model's estimates of total biomass achieve a reasonable relationship with the shelf survey's estimates of biomass? (This is different from the question of how well the model's estimates of *survey* biomass fit the survey's own estimates, which is addressed by the RMSE.)

2. Does the model appropriately reflect the uncertainty associated with key assessment outputs?

Effective Sample Size
Once maximum likelihood estimates of the model parameters have been obtained, SS1 and SS2 compute an "effective" sample size for the size or age composition data specific to a particular year, gear/fishery, and time period within the year. Roughly, the effective sample size can be interpreted as the multinomial sample size that would typically be required in order to produce the given fit. More precisely, it is the sample size that sets the sum of the marginal variances of the proportions implied by the multinomial distribution equal to the sum of the squared differences between the sample proportions and the estimated proportions (McAllister and Ianelli 1997). As a function of a multinomial random variable, the effective sample size has its own distribution. The harmonic mean of the distribution is asymptotically equal to the true sample size in the multinomial distribution. Thus, if the effective sample size is less than the true sample size in the multinomial distribution, it is reasonable to conclude that the fit is not as good as expected. The following table shows the average of the input sample sizes (Ninp), the average of the effective sample sizes (Neff), and the ratio of Neff to Ninp for each of the size composition components and the shelf survey age composition component in each of the three models:

	Model 1			Model 2			Model 3		
Likelihood component	Ninp	Neff	Ratio	Ninp	Neff	Ratio	Ninp	Neff	Ratio
Jan-May trawl fishery length	192	201	1.05	174	217	1.25	174	219	**1.26**
Jun-Dec trawl fishery length	48	98	2.05	45	94	**2.10**	45	92	2.08
Longline fishery length	196	334	**1.70**	196	304	1.55	196	331	1.69
Pot fishery length	106	273	**2.58**	106	231	2.17	106	238	2.24
1996-2003 shelf survey len.	-109	-76	-0.70	-109	-80	-0.74	-109	-82	-0.75
Other years shelf survey len.	104	93	0.90	104	105	1.01	104	112	**1.08**
Slope survey length	23	236	**10.49**	23	104	4.61	23	82	3.65
Shelf survey age	89	34	0.38	89	46	0.52	89	62	**0.70**

Notes:
1) For each row, the average values of Ninp and Neff are computed with respect to all years and periods present in the respective time series.
2) The average input sample sizes for the trawl fishery lengths in Model 1 are slightly different from those in Models 2 and 3 because more years of data are included in Models 2 and 3.
3) The negative values in the row for 1996-2003 shelf survey lengths indicate that those data are "turned off" in the models to avoid double-counting of length data in years with age data..
4) Bold font indicates the maximum ratio for the respective row.

All three models produce average effective sample sizes larger than the average input values for all four commercial fishery length components. All three models produce average effective sample sizes much larger than the average input value for the slope survey length component, which is not surprising, given that the models are using 7 or 8 selectivity parameters to fit only two years' worth of length frequencies. Models 2 and 3 produce average effective sample sizes greater than the average input value for the "other years" shelf survey length component (the years in which no survey age data are available), but the failure of Model 1 to do so may not be particularly meaningful because the true sample sizes for some of those years (1979-1982 and 1988-1989) are unknown. None of the models produces an average effective sample size greater than the average input value for the shelf survey age component, which is somewhat disappointing. Of the seven components (not counting the 1996-2003 shelf survey length component), Model 1 had the highest ratio in three cases, Model 2 had the highest ratio in one case, and Model 3 had the highest ratio in three cases. However, many of the differences between models are extremely small. It should also be noted that the use of prior distributions by Models 2 and 3 might be expected to cause those models to perform less well than Model 1 with respect to likelihood components such as these, but this does not appear to be the case here. In summary, the main conclusion to be drawn from the above table is that all three models are performing reasonably well with respect to most or all of the size composition components.

Fit to Survey Biomass Data

The average value of the lognormal "sigma" parameter in the shelf survey biomass data is 0.099. The log-scale root-mean-squared-errors (log-scale RMSEs) from Models 1, 2, and 3 are 0.190, 0.188, and 0.205, respectively. Although Model 2 performs slightly better than the other two models, all three log-scale RMSEs are approximately twice the value of the average sigma. The inability of any of the three models to achieve a log-scale RMSE close to the average sigma may indicate that simple haul-to-haul sampling variability underestimates the true variability of the shelf survey biomass data. None of the three models came very close to fitting the low biomasses estimated by the survey in 1991 and 1992 or the high survey biomasses estimated in 1994, 1995, 1996, and 2001. If the 1994, 1995, and 1996 points are removed from the time series, the log-scale RMSEs from the three models fall to 0.130, 0.138, and 0.143, respectively, while the average sigma falls to 0.094.

Reasonableness of Parameter Values

Although hundreds of parameters are estimated by all three models, three items of special interest are the natural mortality rate *M*, the shelf survey catchability coefficient *Q* (or *Qmed* in the case of Model 3, where *Q* is allowed to vary annually), and the shelf survey's selectivity at *Lmax*. The values of these parameters (to two significant digits) for each of the three models are shown below:

Parameter	Model 1	Model 2	Model 3
M	0.37	0.37	0.30
Q or Qmed	0.99	0.99	0.82
S(Lmax)	0.16	0.53	0.73

Of course, the values of *M* and *Q* in Models 1 and 2 are fixed rather than estimated, so presumably those values are reasonable. The values of *M* and *Qmed* in Model 3, however, are estimated. The value of *M* estimated in Model 3 is substantially lower than the traditional value of 0.37, but is within the range of published values for the species and is identical to the current estimate of *M* for walleye pollock, the other major gadid species in the Bering Sea. The value of *Qmed* estimated in Model 3 does not exceed 1.0, which is consistent with the results of Somerton (2004). However, it should be noted that the only thing that kept Model 3's estimates of *M* and *Qmed* from moving toward much more extreme values was the use of very strong prior distributions (5% CV). This result is similar to those obtained in the 1997, 1998, and 1999 assessments, where the model tended to produce very low estimates of *M* and very high estimates of *Q*. Nevertheless, the issue of whether statistical estimates of key parameters such as *M* and *Q* are preferable to assumed values merits some discussion. It should be remembered that the traditional *M* value of 0.37 was produced by a model very similar to Model 3, but with fewer data and a less sophisticated estimation algorithm. In this respect, it is difficult to find reasons to support the traditional value of 0.37 over Model 3's estimate of 0.30, except for the sake of consistency.

The values of *S*(*Lmax*) produced by the three models are fairly different from each other. Model 1's estimate of 0.16 is similar to the value of 0.11 estimated in last year's assessment. The estimates given by Models 2 and 3 are much higher and seem easier to reconcile with the design of the survey. A related quantity that may be useful to compare is the product of *Q* (or *Qmed*) and *S*(*Lmax*), since it is this product that determines overall availability to the survey. For Models 2 and 3, the value of this product is 0.53 and 0.60, respectively.

Relationship of Total Biomass to Survey Biomass

The time series of age 3+ biomass, spawning biomass, and survey biomass estimated by the three models, along with the observed survey biomass time series, in Table 2.16. The past several assessments have tended to result in estimates of age 3+ biomass that were much greater than the survey biomass. All three models in the present assessment behave likewise, although the biomass estimates produced by Model 2 and 3 tend not to be as high as those produced by Model 1. On average, the estimates of age 3+ biomass exceed the observed survey biomass by about 94%, 50%, and 51% for Models 1, 2, and 3, respectively.

While it is possible to imagine mechanisms that could cause the bottom trawl survey to underestimate the total biomass of Pacific cod (e.g., a large portion of the population occurring in the water column above the headrope), the existence of any such mechanism has yet to be verified experimentally. Until such verification takes place, age 3+ biomass estimates in the neighborhood of those produced by Models 2 and 3 should probably be viewed as more realistic than estimates in the neighborhood of those produced by Model 1, all else being equal.

The Plan Team addressed this issue in its November, 2004 minutes as follows: *"The team has been concerned that Pacific cod abundance is overestimated. The symptoms are that age 3+ biomass is much greater than observed shelf survey biomass and selectivity for the shelf survey is strongly dome-shaped…. The team recommended that the authors explore the following three questions to understand this difference: 1) The model estimates that large fish are more available to the longline and especially trawl fishery. Are the fisheries concentrated in areas or times where large fish are concentrated? 2) The observed length range for the shelf survey is similar to that for the slope survey, longline fishery, and trawl fishery, yet the selectivity estimated for the shelf survey is strongly dome-shaped. Why? 3) What is the sensitivity of the biomass estimates and selectivity estimates to the assumed value of natural mortality?"*

In response to recommendation #1 from the Plan Team's minutes, Figure 2.1b shows that observed pot hauls in 2004 were concentrated largely in survey stratum 5, observed longline sets in 2004 were concentrated largely in survey strata 5 and 6, and observed trawl hauls in 2004 were concentrated largely in survey strata 3, 5, and 6. Figure 2.6 shows length composition of EBS Pacific cod in the 2004 shelf bottom trawl survey for these three strata and all strata (1-6) combined. As this figure indicates, the size composition in stratum 3 is roughly similar to that of the overall survey, but strata 5 and 6 both have substantially higher proportions of large fish than the overall survey. Therefore, at least in 2004, it does seem to be the case that the fisheries were concentrated in areas where large fish are concentrated, although it should be noted that the issue of intra-annual timing is ignored in Figures 2.1b and 2.6 (specifically, the data used to create Figure 2.1b were collected throughout the year, whereas the data used to create Figure 2.6 were collected during the summer months only).

In response to recommendation #2 from the Plan Team's minutes, it is not clear that the recommendation's premise is valid. Figure 2.7 shows the cumulative frequencies of EBS Pacific cod lengths observed since 2000. This figure demonstrates clearly that the observed lengths from the shelf survey are concentrated in a very different range than the observed lengths in any of the commercial fisheries or the slope survey. For example, the lower bound of the 90% concentration in the shelf survey is about 13 cm, whereas none of the commercial fisheries has a lower bound less than about 41 cm. Likewise, the upper bound of the 90% concentration in the shelf survey is about 65 cm, whereas none of the commercial fisheries has an upper bound less than about 78 cm.

In response to recommendation #3 from the Plan Team's minutes, the relationship between M and selectivity is addressed to some extent under "Reasonableness of Parameter Values" above, whereas some insight into the relationship between M and biomass can be gained from Table 2.16. Although the differences between estimated biomass and selectivity across models cannot be attributed entirely to differences in M, differences in M are likely a major contributing factor.

Along lines similar to the Plan Team's recommendation #3, the SSC has requested that likelihood profiles, or similar measures, be presented for the purpose of understanding consistency between the various data sources (SSC minutes, December 2004). Table 2.17 provides such profiles, using a grid of fixed M and Q values based on Model 2. The range of M values extends from 0.20 to 0.40, in increments of 0.05, and the range of Q values extends from 0.5 to 2.5, in increments of 0.5. Within the set of M and Q values defined by this grid, the log posterior density reached a maximum at M=0.20 and Q=2.0 (note that this maximum occurred at the lower limit of the range of M values considered, meaning that the true global maximum might occur outside the grid). The numbers shown in Table 2.17 represent normalized values of the main components of the log posterior density. The six components consist of the log priors and five log likelihoods: the log likelihood for the length composition data (all gears combined), the log likelihood for the age composition data, the log likelihood for the size-at-age data, the log likelihood for survey biomass, and the log likelihood for the recruitment deviations. For each component and each combination of *M* and *Q*, the value shown in Table 2.17 has been normalized by subtracting it from the value corresponding to *M*=0.20 and *Q*=2.0 for the same component. In other words, under each component, the value shown for *M*=0.20 and *Q*=2.0 is zero, while other cells show positive values if the corresponding *M* and *Q* values yield a better fit (for that component) and negative values if they yield a worse fit (for that component).

One of the main conclusions to be drawn from Table 2.17 is that the length composition likelihood component is where the biggest changes tend to occur. Another conclusion is that the various components are not always consistent (i.e., improving the fit to one component can degrade the fit to another component). Other results of this analysis (not shown in Table 2.17) are that recent values of age 3+ biomass and the equilibrium level of spawning per recruit associated with recent fishing mortality rates can vary widely depending on *M* and *Q*. On the other hand, one measure that does not seem to depend strongly on *M* and *Q* is the recent level of relative variability in age 3+ biomass. The CV associated with the last 10 years of the age 3+ biomass time series ranged only from 4% to 11% for all points on the grid, with an average value of 8%. Thus, regardless of the values of *M* and *Q*, this analysis indicates that recent harvest rates have not led to drastic changes in biomass. However, two caveats apply to this analysis: First, several of the model runs failed to produce a positive definite Hessian matrix (these are indicated by italic font in Table 2.17). Second, all of the model runs fixed the values of σ_R and log-scale pre-1977 mean recruitment at the values associated with Model 2 (where *M* and *Q* are fixed at values of 0.37 and 0.992, respectively), meaning that those two parameters may not be close to equilibrium for some (or many) of the runs used to create the grid.

Characterization of Uncertainty

One of the main drawbacks of SS1 is that it does not include utilities for estimating the statistical uncertainty surrounding derived quantities such as spawning biomass. Because the SS1-based Model 1 provides only point estimates, it can represent uncertainty adequately only if the true uncertainty is very small or if the most important uncertainties consist of natural random variability rather than statistical imprecision. However, because SS2 is coded in ADMB, it provides for straightforward estimation of the statistical uncertainty surrounding any quantity of interest, which gives some hope that the SS2-based Models 2 and 3 can do an adequate job of describing uncertainty. As an example, the three models' estimates of spawning biomass for the years 1978-2005 (the years that all three models have in common) are shown in Figure 2.8, together with 95% confidence intervals for Models 2 and 3. The relative trend of the point estimates is similar across models although the magnitudes differ, with Model 1 consistently giving the highest estimates and Model 2 consistently giving the lowest (the exact relationship between the estimates produced by Models 2 and 3 is obscured during the early years of the time series as a result of staggering the points for ease of plotting), and with the estimates from Models 3 and 2 being closer to each other than the estimates from Models 3 and 1. From the point of view of uncertainty, however, the key feature of Figure 2.8 is that the confidence intervals from Model 3 are noticeably broader than the confidence intervals from Model 2 (Model 1, of course, cannot generate confidence intervals). In fact, the confidence intervals from Model 3 are wide enough that they encompass the point estimates from Models 1 and 2 for every year from 1997 to the present. The fact that Model 3 produces wider confidence intervals than Model 2 is likely due to the fact that natural mortality and survey catchability are estimated in Model 3 but not Model 2.

Selection of Final Model

Evaluation of the three models using the above criteria may be summarized as follows: 1) For the length composition likelihood components, all three models performed at least reasonably well in all categories and performed extremely well in at least some categories. 2) For the age composition likelihood component, none of the three models performed very well, although Model 3 performed better than the other two. 3) For the fit to the survey biomass time series, all three models performed approximately the same, but none of them came very close to fitting the low biomasses estimated by the survey in 1991 and 1992 or the high survey biomasses estimated in 1994, 1995, 1996, and 2001. 4) For the overall reasonableness of the parameter values, all three models are associated with reasonable values of *M* and *Q* (or *Qmed* in the case of Model 3). However, Model 3 has the advantage of being associated with values of *M* and *Qmed* that are not only reasonable but estimated rather than assumed. Model 3 probably gives the most reasonable estimates of large-fish selectivity in the shelf bottom trawl survey, followed fairly closely by Model 2. 5) Relative to the survey biomass time series, the estimated age 3+ biomass time series obtained under Models 2 and 3 were both considerably closer than the time series obtained under Model 1. 6) Regarding characterization of uncertainty, Models 2 and 3 obviously perform better than Model 1, because Model 1 was not designed to produce estimates of uncertainty. Model 3's confidence intervals around spawning biomass are wider than those for Model 2. Given that Model 2's confidence intervals are predicated on the assumption that *M* and *Q* are known with certainty whereas Model 3's confidence intervals do not make this assumption, Model 3's representation of uncertainty is probably more realistic.

On balance, then, Model 3 appears to be the best choice.

Final Parameter Estimates and Associated Schedules
Final estimates of some key scalar parameters are shown below:

Parameter	Value
Length at age 1.5	17.16
Length at age 12	89.36
Brody growth coefficient K	0.134
Natural mortality rate M	0.30
Median shelf survey catchability Qmed	0.82
Temperature-catchability link θ	-0.0022
Recruitment variability σR	0.703

Estimates of fishing mortality rates are shown in Table 2.18, estimates of regime-specific median recruitments and annual recruitment deviations are shown in Table 2.19, estimates of annual shelf survey catchabilities are shown in Table 2.20, and estimates of selectivity parameters are shown in Table 2.21.

Schedules of selectivity at length are shown for the commercial fisheries in Table 2.22a and for the bottom trawl surveys in Table 2.22b. The schedules in Tables 2.22a and 2.22b are plotted in Figure 2.9. As examples of how the schedules of selectivity at length translate into size compositions, Figures 2.10a, 2.10b, 2.10c, 2.11, and 2.12 show observed and estimated size compositions from the 2003 January-May fisheries, the 2004 January-May fisheries, the 2005 January-May fisheries, the 2003-2005 shelf trawl surveys, and the 2002-2004 slope trawl surveys, respectively.

Schedules of selectivity at age for the most recent portion of the time series are shown in Table 2.23 and Figure 2.13. To demonstrate how the schedules of selectivity at length translate into age compositions, Figure 2.14 shows observed and estimated age compositions from the 1996-2003 shelf surveys.

Schedules of length at age, proportion mature at age, and weight at age are shown in Table 2.24.

RESULTS

Definitions

The biomass estimates presented here will be defined in three ways: 1) age 3+ biomass, consisting of the biomass of all fish aged three years or greater in January of a given year; 2) spawning biomass, consisting of the biomass of all spawning females in a given year; and 3) survey biomass, consisting of the biomass of all fish that the model estimates should have been observed by the survey in July of a given year. The recruitment estimates presented here will be defined as numbers of age 0 fish in a given year. The fishing mortality rates presented here will be defined as full-selection, instantaneous fishing mortality rates expressed on a per annum scale.

Biomass
Model 3's estimated time series (1977-2005) of EBS Pacific cod age 3+ biomass and spawning biomass are shown in Table 2.25, together with estimates provided in last year's SAFE report (Thompson and Dorn 2004) and 95% confidence intervals for the spawning biomass estimates from Model 3. The biomass trends (age 3+, spawning, and survey) estimated in the present assessment are also shown in Figure 2.15, with 95% confidence intervals for the spawning biomass estimates. The model's estimated age 3+ biomass shows a near-continual decline from 1987 through 1998, although the trend has been fairly flat since then. The model's estimated spawning biomass shows a similar trend.

Recruitment
Model 3's estimated time series (1977-2004) of age 0 recruitment is shown in Table 2.26, together with estimates inferred from last year's SAFE report (Thompson and Dorn 2004) and 95% confidence intervals for this year's estimates. Because last year's assessment used 1 as the initial age in the model, age 0 recruitments for last year's assessment were inferred here by multiplying last year's estimates of age 1 recruits by exp(0.37), where 0.37 is the value of the natural mortality rate used in last year's assessment. Values for this year's assessment that exceed Model 3's estimate of the 1977-2004 average recruitment of 425,726,964 fish are shown in bold in Table 2.26.

This year's recruitment estimates for the entire time series (1964-2004) are shown in Figure 2.16, along with their respective 95% confidence intervals and regime-specific averages. For the time series as a whole, the largest year class was the 1977 cohort. Other exceptional year classes include those spawned in 1976, 1982, 1984, and 1989. Of the 15 year classes that have followed the strong 1989 year class, only four (1992, 1996, 1999, and 2000) have point estimates higher than the 1977-2004 average, and only three (1992, 1996, and 1999) have confidence intervals that fall entirely above the 1977-2004 average. Five other year classes (1990, 1991, 1995, 1998, and 2004) have point estimates that fall below the 1977-2004 average but confidence intervals that overlap the 1977-2004 average.

To date, it has not been possible to estimate a reliable stock-recruitment relationship for this stock. With the move to SS2, prospects for future estimation of such a relationship should improve. In the interim, Figure 2.17 is provided to give some indication of the relationship between stock and recruitment. The Ricker (1954) curve shown in this figure was not fit statistically, but rather by assuming that $F_{35\%}$ and $B_{35\%}$ correspond to F_{MSY} and B_{MSY}, respectively. This curve is intended to be illustrative only, and is not recommended for management purposes.

Exploitation

The model's estimated time series of the ratio between EBS catch and age 3+ biomass is shown in Table 2.27, together with the estimates provided in last year's SAFE report (Thompson and Dorn 2004). The average value of this ratio over the entire time series is about 0.13, higher than the average value of 0.10 obtained in last year's assessment. The estimated values exceed the average for every year after 1990 except 1993, whereas none of the estimated values exceed the average in any year prior to 1991 except for 1977 and 1978. This finding is basically similar to that obtained in last year's assessment.

Figure 2.18 plots the trajectory of relative fishing mortality and relative female spawning biomass from 1977 through 2005 based on Model 3, overlaid with the current harvest control rules (fishing mortality rates in the figure are standardized relative to $F_{35\%}$ and biomasses are standardized relative to $B_{100\%}$). The entire trajectory lies underneath the F_{OFL} control rule except for the years 1977-1979. For the period 1980-1994, the entire trajectory also fell below the $maxF_{ABC}$ control rule. Since 1995, however, the trajectory has tended to lie very close to the $maxF_{ABC}$ control rule. In the 11 years between 1995 and the present, the trajectory exceeded the $maxF_{ABC}$ control rule seven times and fell below it four times. However, it should be noted that the current harvest control rules did not go into effect until 1999. Nevertheless, the trajectory estimated by Model 3 indicates that the stock has been fished harder in recent years than previously thought (Thompson and Dorn 2004).

PROJECTIONS AND HARVEST ALTERNATIVES

Amendment 56 Reference Points

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, Pacific cod in the BSAI are managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing. The following formulae apply under Tier 3:

3a)Stock status: $B/B_{40\%} > 1$

$F_{OFL} = F_{35\%}$

$F_{ABC} \leq F_{40\%}$

3b)Stock status: $1/20 < B/B_{40\%} \leq 1$

$F_{OFL} = F_{35\%} \times (B/B_{40\%} - 1/20) \times 20/19$

$F_{ABC} \leq F_{40\%} \times (B/B_{40\%} - 1/20) \times 20/19$

3c)Stock status: $B/B_{40\%} \leq 1/20$

$F_{OFL} = 0$

$F_{ABC} = 0$

Estimation of the $B_{40\%}$ reference point used in the above formulae requires an assumption regarding the equilibrium level of recruitment. In this assessment, it is assumed that the equilibrium level of recruitment is equal to the post-1976 average (i.e., the arithmetic mean of all estimated recruitments from year classes spawned in 1977 or later). Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. These reference points are estimated as follows:

Reference point:	$B_{35\%}$	$B_{40\%}$	$B_{100\%}$
BSAI:	302,000 t	345,000 t	863,000 t
EBS:	257,000 t	293,000 t	734,000 t

For a stock exploited by multiple gear types, estimation of $F_{35\%}$ and $F_{40\%}$ requires an assumption regarding the apportionment of fishing mortality among those gear types. For this assessment, the apportionment was based on Model 3's estimates of fishing mortality by gear for the three most recent complete years of data (2002-2004). The average fishing mortality rates for those years implied that total fishing mortality was divided among the three main gear types according to the following percentages: trawl 30.6%, longline 59.0%, and pot 10.4%. This apportionment results in estimates of $F_{35\%}$ and $F_{40\%}$ equal to 0.38 and 0.32, respectively. These are different from last year's estimates of 0.43 and 0.36 for a number of reasons, two of which are the use of a new maturity schedule and new estimate of M (0.30) in this year's assessment.

Specification of OFL and Maximum Permissible ABC

BSAI spawning biomass for 2006 is estimated at a value of 334,000 t (EBS value = 283,000 t). This is about 3% below the BSAI $B_{40\%}$ value of 345,000 t (EBS value = 293,000 t), thereby placing Pacific cod in sub-tier "b" of Tier 3. Given this, the model estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2006 as follows:

Quantity	Overfishing Level	Maximum Permissible ABC
EBS catch:	184,000 t	156,000 t
BSAI catch:	216,000 t	183,000 t
Fishing mortality rate:	0.37	0.31

The age 3+ biomass estimates for 2006 are 1,050,000 t and 893,000 t for the BSAI and EBS, respectively.

ABC Recommendation

Review of Past Approaches

BSAI Pacific cod ABCs for the years 1998-2002 were based on a harvest strategy that attempted to address some of the statistical uncertainty in the assessment model, namely the uncertainty surrounding parameters the natural mortality rate M and survey catchability Q (Thompson and Dorn 1997, 1998, 1999). For the 2001-2002 ABCs, the strategy was simplified by assuming that the ratio between the recommended F_{ABC} and $F_{40\%}$ estimate given in the 1999 assessment (0.87) was an appropriate factor by which to multiply the current maximum permissible F_{ABC} to obtain a recommended F_{ABC} (Thompson and Dorn 2001). For the 2003 and 2004 ABCs, concerns regarding the performance of the assessment model led to a decision that kept ABC constant at the 2002 level of 223,000 t, well below the maximum permissible level estimated in the respective assessments (Thompson and Dorn 2002, 2003). In the 2004 assessment (Thompson and Dorn 2004), the maximum permissible value for the 2005 ABC was estimated to be 227,000 t, only slightly higher than the 2003-2004 ABCs of 223,000 t. Because the 2003-2004 "constant catch" ABCs were intended to provide a precautionary alternative to the model's maximum permissible ABCs, it seemed appropriate in last year's assessment to consider another method for recommending ABC. This method was based on a consideration of the mean-variance tradeoff associated with future catches predicted by the standard projection model, and resulted in a 2005 ABC of 206,000 t.

Recommendation for 2006

Based on Model 3, the maximum permissible ABC (Tier 3b) for 2006 is 183,000 t. To provide some context for this value, the time series of ABCs for the 15 years following 1990 shows that ABC has ranged from a low of 164,500 t to a high of 328,000 t, with an average of about 223,000 t, (Table 2.4). A 2006 ABC of 183,000 t would be the fourth lowest ABC since 1990, and the decrease from the 2005 ABC (23,000 t or 11%) would represent the fifth largest one-year decrease in the time series since 1990. Given the magnitude of this decrease and the fact that it follows immediately on the heals of a decrease almost as large, it would not be prudent to recommend an ABC lower than the maximum permissible value for 2006. Therefore, 183,000 t is the recommended ABC for 2006. It should be noted that Model 3 projects the maximum permissible ABC to continue declining for the next few years.

Area Allocation of Harvests

At present, ABC of BSAI Pacific cod is not allocated by area. Pacific cod is something of an exception in this regard. Based on a Kalman filter analysis of the shelf bottom trawl survey time series in the EBS and AI, last year's assessment concluded that the best estimate of the BSAI Pacific cod biomass distribution was 85% EBS and 15% AI (Thompson and Dorn 2004). The analysis was not repeated for this year's assessment, because no AI survey was conducted this year. If a 2006 ABC of 183,000 t were apportioned accordingly, the EBS and AI portions would be 156,000 t and 27,000 t, respectively (rounded to the nearest thousand t). An ABC of 27,000 t in the AI would be about 6% lower than the 2004 AI catch of 28,865 t. Thus, if there were no other management complications, setting a separate ABC for the AI would be expected to impose only a modest new constraint on the existing fishery while helping to control future expansion of the fishery in this area. However, at present, there are potentially significant management complications arising from certain allocation formulas (by gear type, CDQ, etc.) pertaining to Pacific cod in the Fishery Management Plan. Until such time as these complications can be resolved, specification of separate ABCs for the EBS and AI is not recommended.

Standard Harvest and Recruitment Scenarios and Projection Methodology

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2005 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2006 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2005. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2006, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2006 recommended in the assessment to the *max* F_{ABC} for 2006. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)
>
> *Scenario 3*: In all future years, F is set equal to 50% of *max* F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 2001-2005 average F, which was 0.23. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2006 or 2) above ½ of its MSY level in 2006 and above its MSY level in 2016 under this scenario, then the stock is not overfished.)

Scenario 7: In 2006 and 2007, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2018 under this scenario, then the stock is not approaching an overfished condition.)

Projections and Status Determination

Scenario Projections and Two-Year Ahead Overfishing Level
Table 2.28 defines symbols used to describe projections of spawning biomass, fishing mortality rate, and catch corresponding to the seven standard harvest scenarios. These projections are shown for Model 3 in Tables 2.29-34.

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2006 (216,000 t), it does not provide the best estimate of OFL for 2007, because the mean 2007 catch under Scenario 6 is predicated on the 2006 catch being equal to the 2006 OFL, whereas the actual 2006 catch will likely be less than the 2006 OFL. Therefore, the projection model was re-run with the 2006 catch fixed at the recommended 2006 ABC value of 183,000 t and the 2007 fishing mortality rate fixed at F_{OFL}. The resulting estimate of the 2007 OFL was 184,000 t.

Status Determination
Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock overfished? This depends on the stock's estimated spawning biomass in 2006:

a. If spawning biomass for 2006 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2006 is estimated to be above $B_{35\%}$ the stock is above its MSST.

c. If spawning biomass for 2006 is estimated to be above ½ $B_{35\%}$ but below B35%, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 2.33). If the mean spawning biomass for 2016 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7 (Table 2.34):

a. If the mean spawning biomass for 2008 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2008 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2008 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2018. If the mean spawning biomass for 2018 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

In the case of BSAI Pacific cod, spawning biomass for 2006 is estimated to be above $B_{35\%}$. Therefore, the stock is above its MSST and is not overfished. Mean spawning biomass for 2008 in Table 2.34 is above ½ $B_{35\%}$ but below $B_{35\%}$, and mean spawning biomass for 2018 is above $B_{35\%}$. Therefore, the stock is not approaching an overfished condition.

ECOSYSTEM CONSIDERATIONS

Ecosystem Effects on the Stock

A primary ecosystem phenomenon affecting the Pacific cod stock seems to be the occurrence of periodic “regime shifts,” in which central tendencies of key variables in the physical environment change on a scale spanning several years to a few decades (Boldt (ed.), 2005). One well-documented example of such a regime shift occurred in 1977, and shifts occurring in 1989 and 1999 have also been suggested (e.g., Hare and Mantua 2000). In the present assessment, an attempt was made to estimate the change in median recruitment of EBS Pacific cod associated with the 1977 regime shift. According to Model 3, pre-1977 median recruitment was only about 28% of post-1976 median recruitment. Establishing a link between environment and recruitment within a particular regime is more difficult. In last year’s assessment (Thompson and Dorn 2004), for example, the correlations between age 1 recruits spawned since 1977 and monthly values of the Pacific Decadal Oscillation (Mantua et al. 1997) were computed and found to be very weak.

The prey and predators of Pacific cod have been described or reviewed by Albers and Anderson (1985), Livingston (1989, 1991), Lang et al. (2003), Westrheim (1996), and Yang (2004). The composition of Pacific cod prey varies to some extent by time and area. In terms of percent occurrence, some of the most important items in the diet of Pacific cod in the BSAI and GOA have been polychaetes, amphipods, and crangonid shrimp. In terms of numbers of individual organisms consumed, some of the most important dietary items have been euphausids, miscellaneous fishes, and amphipods. In terms of weight of organisms consumed, some of the most important dietary items have been walleye pollock, fishery offal, yellowfin sole, and crustaceans. Small Pacific cod feed mostly on invertebrates, while large Pacific cod are mainly piscivorous. Predators of Pacific cod include Pacific cod, halibut, salmon shark, northern fur seals, Steller sea lions, harbor porpoises, various whale species, and tufted puffin. Major trends in the most important prey or predator species could be expected to affect the dynamics of Pacific cod to some extent.

Fishery Effects on the Ecosystem

Potentially, fisheries for Pacific cod can have effects on other species in the ecosystem through a variety of mechanisms, for example by relieving predation pressure on shared prey species (i.e., species which serve as prey for both Pacific cod and other species), by reducing prey availability for predators of Pacific cod, by altering habitat, by imposing bycatch mortality, or by “ghost fishing” caused by lost fishing gear.

Bycatch of Nontarget and "Other" Species

Bycatch of nontarget species and members of the "other species" group are shown in the following set of tables (for the 2003-2005 tables, the "hook and line" gear type includes both longline and jig gear): Tables 2.35a and 2.35b show bycatch for the EBS Pacific cod trawl fishery in 1997-2002 and 2003-2005, respectively. Tables 2.36a and 2.36b show bycatch for the EBS Pacific cod longline fishery in 1997-2002 and the EBS Pacific cod hook and line fishery in 2003-2005, respectively. Tables 2.37a and 2.37b show bycatch for the EBS Pacific cod pot fishery in 1997-2002 and 2003-2005, respectively. Tables 2.38a and 2.38b show bycatch for the AI Pacific cod trawl fishery in 1997-2002 and 2003-2005, respectively. Tables 2.39a and 2.39b show bycatch for the AI Pacific cod longline fishery in 1997-2002 and the AI Pacific cod hook and line fishery in 2003-2005, respectively. Tables 2.40 shows bycatch for the AI Pacific cod pot fishery in 1997-2002 (no data exist for this fishery in 2003-2005).

It is not clear how much bycatch of a particular species constitutes "too much" in the context of ecosystem concerns. As a first step toward possible prioritization of future investigation into this question, it might be reasonable to focus on those species groups for which a Pacific cod fishery had a bycatch in excess of 100 t and accounted for more than 10% of the total bycatch in at least two of the three most recent years. This criterion results in the following list of impacted species groups (an "X" indicates that the criterion was met for that area/species/gear combination).

Area	Species group	Trawl	Hook and Line
EBS	Grenadier		X
EBS	Large sculpins	X	X
EBS	Misc. fish	X	
EBS	Other sculpins		X
EBS	Shark		X
EBS	Skate		X
AI	Skate		X

Steller Sea Lions

Sinclair and Zeppelin (2002) showed that Pacific cod was one of the four most important prey items of Steller sea lions in terms of frequency of occurrence averaged over years, seasons, and sites, and was especially important in winter. Pitcher (1981) and Calkins (1998) also showed Pacific cod to be an important winter prey item in the GOA and BSAI, respectively. Furthermore, the size ranges of Pacific cod harvested by the fisheries and consumed by Steller sea lions overlap, and the fishery operates to some extent in the same geographic areas used by Steller sea lion as foraging grounds (Livingston (ed.), 2002).

The Fisheries Interaction Team of the Alaska Fisheries Science Center has been engaged in research to determine the effectiveness of recent management measures designed to mitigate the impacts of the Pacific cod fisheries (among others) on Steller sea lions. Results from studies conducted in 2002-2003 were summarized by Conners et al. (2004). These studies included a tagging feasibility study, which may evolve into an ongoing research effort capable of providing information on the extent and rate to which Pacific cod move in and out of various portions of Steller sea lion critical habitat. Nearly 6,000 spaghetti tags were released, of which approximately 1,000 had been returned as of September, 2003.

Seabirds

The following is a summary of information provided by Livingston (ed., 2002): In both the BSAI and GOA, the northern fulmar (*Fulmarus glacialis*) comprises the majority of seabird bycatch, which occurs primarily in the longline fisheries, including the hook and line fishery for Pacific cod (Tables 2.36b and 2.39b). Shearwater (*Puffinus* spp.) distribution overlaps with the Pacific cod longline fishery in the Bering Sea, and with trawl fisheries in general in both the Bering Sea and GOA. Black-footed albatross (*Phoebastria nigripes*) is taken in much greater numbers in the GOA longline fisheries than the Bering Sea longline fisheries, but is not taken in the trawl fisheries. The distribution of Laysan albatross

(*Phoebastria immutabilis*) appears to overlap with the longline fisheries in the central and western Aleutians. The distribution of short-tailed albatross (*Phoebastria albatrus*) also overlaps with the Pacific cod longline fishery along the Aleutian chain, although the majority of the bycatch has taken place along the northern portion of the Bering Sea shelf edge (in contrast, only two takes have been recorded in the GOA). Some success has been obtained in devising measures to mitigate fishery-seabird interactions. For example, on vessels larger than 60 ft. LOA, paired streamer lines of specified performance and material standards have been found to reduce seabird incidental take significantly.

Fishery Usage of Habitat

The following is a summary of information provided by Livingston (ed., 2002): The longline and trawl fisheries for Pacific cod each comprise an important component of the combined fisheries associated with the respective gear type in each of the three major management regions (BS, AI, and GOA). Looking at each gear type in each region as a whole (i.e., aggregating across all target species) during the period 1998-2001, the total number of observed sets was as follows:

Gear	BS	AI	GOA
Trawl	240,347	43,585	68,436
Longline	65,286	13,462	7,139

In the BS, both longline and trawl effort was concentrated north of False Pass (Unimak Island) and along the shelf edge represented by the boundary of areas 513, 517 (in addition, longline effort was concentrated along the shelf edge represented by the boundary of areas 521-533). In the AI, both longline and trawl effort was dispersed over a wide area along the shelf edge. The catcher vessel longline fishery in the AI occurred primarily over mud bottoms. Longline catcher-processors in the AI tended to fish more over rocky bottoms. In the GOA, fishing effort was also dispersed over a wide area along the shelf, though pockets of trawl effort were located near Chirikof, Cape Barnabus, Cape Chiniak and Marmot Flats. The GOA longline fishery for Pacific cod generally took place over gravel, cobble, mud, sand, and rocky bottoms, in depths of 25 fathoms to 140 fathoms.

Impacts of the Pacific cod fisheries on essential fish habitat were further analyzed in an environmental impact statement by NMFS (2005).

Data Gaps and Research Priorities

Understanding of the above ecosystem considerations would be improved if future research were directed toward closing certain data gaps. Such research would have several foci, including the following: 1) ecology of the Pacific cod stock, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment; 2) behavior of the Pacific cod fishery, including spatial dynamics; 3) determinants of trawl survey selectivity; 4) ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience; and 5) ecology of species that interact with Pacific cod, including estimation of biomass, carrying capacity, and resilience.

SUMMARY

The major results of the Pacific cod stock assessment are summarized in Table 2.41.

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Table 2.1a—Summary of 1964-1980 catches (t) of Pacific cod in the Eastern Bering Sea by fleet sector. Catches by gear are not available for these years. Catches may not always include discards.

Eastern Bering Sea only:

Year	Foreign	Joint Venture	Domestic	Total
1964	13408	0	0	13408
1965	14719	0	0	14719
1966	18200	0	0	18200
1967	32064	0	0	32064
1968	57902	0	0	57902
1969	50351	0	0	50351
1970	70094	0	0	70094
1971	43054	0	0	43054
1972	42905	0	0	42905
1973	53386	0	0	53386
1974	62462	0	0	62462
1975	51551	0	0	51551
1976	50481	0	0	50481
1977	33335	0	0	33335
1978	42512	0	31	42543
1979	32981	0	780	33761
1980	35058	8370	2433	45861

Table 2.1b—Summary of 1981-2005 catches (t) of Pacific cod in the Eastern Bering Sea by fleet sector and gear type. All catches include discards. LLine = longline, Subt. = sector subtotal. Catches for 2005 are through early October.

Eastern Bering Sea only:

	Foreign			Joint Venture		Domestic Annual Processing					
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1981	30347	5851	36198	7410	7410	12884	1	0	14	12899	56507
1982	23037	3142	26179	9312	9312	23893	5	0	1715	25613	61104
1983	32790	6445	39235	9662	9662	45310	4	21	569	45904	94801
1984	30592	26642	57234	24382	24382	43274	8	0	205	43487	125103
1985	19596	36742	56338	35634	35634	51425	50	0	0	51475	143447
1986	13292	26563	39855	57827	57827	37646	48	62	167	37923	135605
1987	7718	47028	54746	47722	47722	46039	1395	1	0	47435	149903
1988	0	0	0	106592	106592	93706	2474	299	0	96479	203071
1989	0	0	0	44612	44612	119631	13935	145	0	133711	178323
1990	0	0	0	8078	8078	115493	47114	1382	0	163989	172067
1991	0	0	0	0	0	129392	76734	3343	0	209469	209469
1992	0	0	0	0	0	77259	80174	7512	33	164978	164978
1993	0	0	0	0	0	81790	49295	2098	2	133185	133185
1994	0	0	0	0	0	84931	78566	8037	730	172264	172264
1995	0	0	0	0	0	110956	97665	19275	599	228496	228496
1996	0	0	0	0	0	91910	88882	28006	267	209064	209064
1997	0	0	0	0	0	93924	117008	21493	173	232598	232598
1998	0	0	0	0	0	60780	84323	13232	192	158526	158526
1999	0	0	0	0	0	51902	81463	12399	100	145865	145865
2000	0	0	0	0	0	53815	81640	15849	68	151372	151372
2001	0	0	0	0	0	35655	90360	16385	52	142452	142452
2002	0	0	0	0	0	51065	100269	15051	166	166552	166552
2003	0	0	0	0	0	47580	106967	21957	155	176659	176659
2004	0	0	0	0	0	57784	109692	17238	231	184945	184945
2005	0	0	0	0	0	52103	77686	13600	103	143492	143492

Table 2.2a—Summary of 1964-1980 catches (t) of Pacific cod in the Aleutian Islands region by fleet sector. Catches by gear are not available for these years. Catches may not always include discards.

Aleutian Islands region only:

Year	Foreign	Joint Venture	Domestic	Total
1964	241	0	0	241
1965	451	0	0	451
1966	154	0	0	154
1967	293	0	0	293
1968	289	0	0	289
1969	220	0	0	220
1970	283	0	0	283
1971	2078	0	0	2078
1972	435	0	0	435
1973	977	0	0	977
1974	1379	0	0	1379
1975	2838	0	0	2838
1976	4190	0	0	4190
1977	3262	0	0	3262
1978	3295	0	0	3295
1979	5593	0	0	5593
1980	5788	0	0	5788

Table 2.2b—Summary of 1981-2005 catches (t) of Pacific cod in the Aleutian Islands region by fleet sector and gear type. All catches include discards. LLine = longline, Subt. = sector subtotal. Catches for 2005 are through early October.

Aleutian Islands region only:

	Foreign			Joint Venture		Domestic Annual Processing					
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1981	2680	235	2915	1749	1749	2744	26	0	0	2770	7434
1982	1520	476	1996	4280	4280	2121	0	0	0	2121	8397
1983	1869	402	2271	4700	4700	1459	0	0	0	1459	8430
1984	473	804	1277	6390	6390	314	0	0	0	314	7981
1985	10	829	839	5638	5638	460	0	0	0	460	6937
1986	5	0	5	6115	6115	784	1	1	0	786	6906
1987	0	0	0	10435	10435	2662	22	88	0	2772	13207
1988	0	0	0	3300	3300	1698	137	30	0	1865	5165
1989	0	0	0	6	6	4233	284	19	0	4536	4542
1990	0	0	0	0	0	6932	602	7	0	7541	7541
1991	0	0	0	0	0	3414	3203	3180	0	9797	9797
1992	0	0	0	0	0	14558	22108	6317	84	43068	43068
1993	0	0	0	0	0	17312	16860	0	33	34204	34204
1994	0	0	0	0	0	14382	7009	147	0	21539	21539
1995	0	0	0	0	0	10574	4935	1024	0	16534	16534
1996	0	0	0	0	0	21179	5819	4611	0	31609	31609
1997	0	0	0	0	0	17349	7151	575	89	25164	25164
1998	0	0	0	0	0	20531	13771	424	0	34726	34726
1999	0	0	0	0	0	16437	7874	3750	69	28130	28130
2000	0	0	0	0	0	20362	16183	3107	33	39684	39684
2001	0	0	0	0	0	15826	17817	544	19	34207	34207
2002	0	0	0	0	0	27929	2865	7	0	30801	30801
2003	0	0	0	0	0	31478	974	2	0	32455	32455
2004	0	0	0	0	0	25766	3099	0	0	28865	28865
2005	0	0	0	0	0	18975	1923	0	13	20911	20911

Table 2.3a—Summary of 1964-1980 catches (t) of Pacific cod in the combined Eastern Bering Sea and Aleutian Islands region by fleet sector. Catches by gear are not available for these years. Catches may not always include discards.

Eastern Bering Sea and Aleutian Islands region combined:

Year	Foreign	Joint Venture	Domestic	Total
1964	13649	0	0	13649
1965	15170	0	0	15170
1966	18354	0	0	18354
1967	32357	0	0	32357
1968	58191	0	0	58191
1969	50571	0	0	50571
1970	70377	0	0	70377
1971	45132	0	0	45132
1972	43340	0	0	43340
1973	54363	0	0	54363
1974	63841	0	0	63841
1975	54389	0	0	54389
1976	54671	0	0	54671
1977	36597	0	0	36597
1978	45807	0	31	45838
1979	38574	0	780	39354
1980	40846	8370	2433	51649

Table 2.3b—Summary of 1981-2005 catches (t) of Pacific cod in the combined Eastern Bering Sea and Aleutian Islands region by fleet sector and gear type. All catches include discards. LLine = longline, Subt. = sector subtotal. Catches for 2005 are through early October.

Eastern Bering Sea and Aleutian Islands region combined:

	Foreign			Joint Venture		Domestic Annual Processing					
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LLine	Pot	Other	Subt.	Total
1981	33027	6086	39113	9159	9159	15628	27	0	14	15669	63941
1982	24557	3618	28175	13592	13592	26014	5	0	1715	27734	69501
1983	34659	6847	41506	14362	14362	46769	4	21	569	47363	103231
1984	31065	27446	58511	30772	30772	43588	8	0	205	43801	133084
1985	19606	37571	57177	41272	41272	51885	50	0	0	51935	150384
1986	13297	26563	39860	63942	63942	38430	49	63	167	38709	142511
1987	7718	47028	54746	58157	58157	48701	1417	89	0	50207	163110
1988	0	0	0	109892	109892	95404	2611	329	0	98344	208236
1989	0	0	0	44618	44618	123864	14219	164	0	138247	182865
1990	0	0	0	8078	8078	122425	47716	1389	0	171530	179608
1991	0	0	0	0	0	132806	79937	6523	0	219266	219266
1992	0	0	0	0	0	91818	102282	13829	117	208046	208046
1993	0	0	0	0	0	99102	66155	2098	35	167389	167389
1994	0	0	0	0	0	99313	85575	8184	730	193802	193802
1995	0	0	0	0	0	121530	102600	20299	599	245029	245029
1996	0	0	0	0	0	113089	94701	32617	267	240673	240673
1997	0	0	0	0	0	111273	124159	22068	262	257762	257762
1998	0	0	0	0	0	81310	98094	13657	192	193253	193253
1999	0	0	0	0	0	68339	89337	16150	169	173995	173995
2000	0	0	0	0	0	74177	97823	18956	101	191056	191056
2001	0	0	0	0	0	51482	108177	16929	71	176659	176659
2002	0	0	0	0	0	78994	103134	15058	166	197352	197352
2003	0	0	0	0	0	79059	107941	21959	156	209114	209114
2004	0	0	0	0	0	83550	112790	17239	231	213810	213810
2005	0	0	0	0	0	71078	79609	13600	116	164404	164404

Table 2.4—History of Pacific cod ABC, TAC, total BSAI catch, and type of stock assessment model used to recommend ABC. Catch for 2005 is current through early October. "SS1" refers to Stock Synthesis 1. Each cell in the "Stock Assessment Model" column lists the type of model used to recommend the ABC in the corresponding row, meaning that the model was produced in the year previous to the one listed in the corresponding row.

Year	ABC	TAC	Catch	Stock assessment model (from previous year)
1980	148,000	70,700	45,947	projection of 1979 survey numbers at age
1981	160,000	78,700	63,941	projection of 1979 survey numbers at age
1982	168,000	78,700	69,501	projection of 1979 survey numbers at age
1983	298,200	120,000	103,231	projection of 1979 survey numbers at age
1984	291,300	210,000	133,084	projection of 1979 survey numbers at age
1985	347,400	220,000	150,384	projection of 1979-1985 survey numbers at age
1986	249,300	229,000	142,511	separable age-structured model
1987	400,000	280,000	163,110	separable age-structured model
1988	385,300	200,000	208,236	separable age-structured model
1989	370,600	230,681	182,865	separable age-structured model
1990	417,000	227,000	179,608	separable age-structured model
1991	229,000	229,000	219,266	separable age-structured model
1992	182,000	182,000	208,046	SS1 model (age-based data)
1993	164,500	164,500	167,389	SS1 model (length-based data)
1994	191,000	191,000	193,802	SS1 model (length-based data)
1995	328,000	250,000	245,029	SS1 model (length-based data)
1996	305,000	270,000	240,673	SS1 model (length-based data)
1997	306,000	270,000	257,762	SS1 model (length-based data)
1998	210,000	210,000	193,253	SS1 model (length-based data)
1999	177,000	177,000	173,995	SS1 model (length-based data)
2000	193,000	193,000	191,056	SS1 model (length-based data)
2001	188,000	188,000	176,659	SS1 model (length-based data)
2002	223,000	200,000	197,352	SS1 model (length-based data)
2003	223,000	207,500	209,114	SS1 model (length-based data)
2004	223,000	215,500	213,810	SS1 model (length-based data)
2005	206,000	206,000	164,404	SS1 model (length- and age-based data)

Table 2.5a—Pacific cod discard rates by area, target species/group, and year for the period 1991-2002 (see Table 2.5b for the period 2003-2004). The discard rate is the ratio of discarded Pacific cod catch to total Pacific cod catch for a given area/target/year combination. An empty cell indicates that no Pacific cod were caught in that area/target/year combination. Note that the absolute amount of discards may be small even if the discard rate is large.

Eastern Bering Sea

Target species/group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Arrowtooth flounder	0.61	0.00	0.94		0.66	0.08	0.07	1.00	1.00	0.99	1.00	0.22
Atka mackerel	1.00		0.70	1.00		0.23		0.51	0.00	0.00	1.00	
Flathead sole					0.39	0.58	0.10	0.75	0.87	0.75	0.00	1.00
Greenland turbot	0.01	0.00	0.12	0.04	0.35	0.09	0.03	0.04	0.13	0.10	0.01	0.18
Other flatfish	0.63	0.31	0.47	0.88	0.22	0.28	0.91	0.28	0.33	0.32	0.00	0.00
Other species	0.04	0.99	0.38		1.00	1.00	0.01	0.95	0.07	0.92	0.08	0.00
Pacific cod	0.03	0.04	0.08	0.06	0.07	0.04	0.03	0.02	0.01	0.02	0.01	0.02
Pollock	0.70	0.85	0.73	0.68	0.21	0.41	0.24	0.42	0.49	0.68	0.84	0.52
Rock sole	1.00	0.00	0.08	0.87	0.25	0.90		1.00	0.02	0.16	1.00	1.00
Rockfish	1.00	0.00	0.89	0.01	0.84	0.69	0.16		0.00	0.03	0.00	0.00
Sablefish	0.00	0.12	0.42	0.40	0.96	0.94	0.78	0.93	0.61	0.98	0.12	0.48
Unknown	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.49	0.04	0.02		
Yellowfin sole		0.74	0.72	0.50	0.08	1.00	0.24	0.77	0.50	0.60	0.39	0.77
All targets	0.03	0.04	0.08	0.06	0.07	0.04	0.03	0.02	0.01	0.02	0.01	0.02

Aleutian Islands

Target species/group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Arrowtooth flounder	1.00										0.00	0.00
Atka mackerel								1.00		1.00	1.00	1.00
Flathead sole		0.35										
Greenland turbot	0.11	0.00	0.73	0.58	0.40	0.89	0.04	0.01	0.18	0.40	0.00	0.00
Other species		1.00			0.00				0.14	0.08	0.00	0.06
Pacific cod	0.02	0.03	0.12	0.09	0.04	0.04	0.05	0.02	0.02	0.02	0.01	0.02
Pollock	0.76	0.00	0.29	0.00	0.47	0.74	0.75	0.61	0.00			
Rock sole			0.00									
Rockfish	0.83		0.75	0.28	0.18	0.80	0.91	1.00	0.64	0.12	0.22	0.03
Sablefish	1.00	0.04	0.49	0.52	0.97	0.53	0.70	0.88	0.51	0.31	0.06	0.76
Unknown	0.09				1.00	1.00		0.03		1.00	1.00	
All targets	0.04	0.03	0.12	0.09	0.12	0.04	0.06	0.02	0.02	0.02	0.01	0.02

Table 2.5b—Pacific cod discard rates by area, target species/group, and year for the period 2003-2004 (see Table 2.5a for the period 1991-2002; note that the IFQ halibut target does not exist in Table 2.5a). The discard rate is the ratio of discarded Pacific cod catch to total Pacific cod catch for a given area/target/year combination. An empty cell indicates that no Pacific cod were caught in that area/target/year combination. Note that the absolute amount of discards may be small even if the discard rate is large.

	Eastern Bering Sea			**Aleutian Islands**	
Target species/group	2003	2004		2003	2004
Arrowtooth flounder	0.01	0.00			
Atka mackerel	0.02	0.00		0.03	0.02
Flathead sole	0.00	0.02			
Greenland turbot	0.07	0.05		0.00	
IFQ halibut	0.28	0.28		0.58	0.38
Other flatfish	0.02	0.00			
Other species	0.02	0.04		0.00	
Pacific cod	0.01	0.01		0.01	0.01
Pollock	0.00	0.02			
Rock sole	0.08	0.03		0.11	
Rockfish	0.00	0.00		0.00	0.02
Sablefish	0.44	0.03		0.37	0.06
Unknown					
Yellowfin sole	0.06	0.02			
All targets	0.02	0.01		0.01	0.01

Table 2.6a—EBS catch (t) of Pacific cod by year, gear, and period for the years 1964-1980. Because direct estimates of gear- and period-specific catches are not available for these years, the figures shown here are estimates derived by distributing each year's total catch according to the average proportion observed for each gear/period combination during the years 1981-1988.

Year	Trawl Fishery			Longline Fishery			Pot Fishery		
	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
1964	6007	2469	2759	744	105	1324	0	0	0
1965	6595	2711	3028	817	115	1453	0	0	0
1966	8154	3352	3744	1011	142	1797	0	0	0
1967	14366	5905	6597	1780	250	3166	0	0	0
1968	25942	10663	11913	3215	452	5718	0	0	0
1969	22559	9272	10359	2796	393	4972	0	0	0
1970	31404	12908	14421	3892	547	6922	0	0	0
1971	19289	7929	8858	2391	336	4252	0	0	0
1972	19223	7901	8827	2382	335	4237	0	0	0
1973	23918	9831	10984	2964	417	5272	0	0	0
1974	27985	11503	12851	3468	487	6168	0	0	0
1975	23096	9493	10606	2862	402	5091	0	0	0
1976	22617	9296	10386	2803	394	4985	0	0	0
1977	14935	6139	6858	1851	260	3292	0	0	0
1978	19710	8101	9051	2443	343	4344	0	0	0
1979	16131	6630	7407	1999	281	3555	0	0	0
1980	18387	7558	8444	2279	320	4053	0	0	0

Table 2.6b—EBS catch (t) of Pacific cod by year, gear, and period for the years 1981-2005. Period 3 catch values for 2005 are extrapolations based on the average values from the previous three years.

Year	Trawl Fishery			Longline Fishery			Pot Fishery		
	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
1981	15067	14087	21486	1286	624	3942	0	0	0
1982	21742	18151	16348	363	475	2308	0	0	0
1983	40757	24300	22705	2941	748	2756	0	0	0
1984	48237	24964	25045	5012	2128	19508	0	0	0
1985	55673	28673	22310	13703	1710	21379	0	0	0
1986	59786	26598	22382	8895	438	17278	0	0	0
1987	64413	15604	21462	20947	723	26752	0	0	0
1988	127470	25662	47166	444	646	1385	90	51	160
1989	127459	16986	19798	3810	4968	5157	33	63	49
1990	101645	11402	10524	13171	16643	17299	0	986	395
1991	107979	15549	5863	25470	21472	29792	12	1042	2288
1992	59460	11840	5959	49696	24201	6276	2622	4632	258
1993	67148	5362	9280	49244	27	23	2073	24	0
1994	61009	5806	18115	57968	13	20585	4923	0	3113
1995	90366	8543	12047	68458	26	29180	12484	3469	3322
1996	78194	3126	10590	62011	26	26845	18143	6401	3462
1997	81313	3927	8684	70676	43	46290	14584	3576	3333
1998	45008	5603	10169	54234	18	30071	9022	2779	1432
1999	44904	3312	3686	55180	1923	24360	9346	1001	2052
2000	44508	4578	4730	40180	1375	40086	15742	0	107
2001	22849	7025	5781	38368	6700	45291	11645	442	4298
2002	37008	9554	4503	50024	12132	38113	10852	401	3799
2003	34515	9986	3079	53156	11032	42773	15452	74	6586
2004	42181	12407	3197	56050	10459	43183	12560	521	4388
2005	44954	6676	3593	53176	12637	41357	12020	78	4924

Table 2.7—Pacific cod length sample sizes from the commercial fisheries. Data for 2005 are current through early October.

	Trawl Fishery			Longline Fishery			Pot Fishery		
Year	Per. 1	Per. 2	Per. 3	Per. 1	Per. 2	Per. 3	Per. 1	Per. 2	Per. 3
1974	58	0	99	0	0	0	0	0	0
1975	253	58	0	0	0	0	0	0	0
1977	227	515	10	0	0	0	0	0	0
1978	646	0	3161	2885	4886	2514	0	0	0
1979	1667	0	748	11410	2514	2662	0	0	0
1980	1359	73	327	2600	1389	2932	0	0	0
1981	132	0	1540	2253	1276	1300	0	0	0
1982	592	226	1643	2910	1203	5078	0	0	0
1983	12386	1231	14577	18800	4119	9610	0	0	0
1984	10246	4482	4477	6853	6004	82103	0	0	0
1985	30171	1556	3051	0	4561	134469	0	0	0
1986	28566	1813	2548	18588	200	104142	0	0	0
1987	46360	6674	20923	70273	0	165124	0	0	0
1988	103453	0	2897	0	0	0	0	0	0
1989	58575	612	669	0	0	0	0	0	0
1990	64143	9807	250	18900	74534	62550	0	1506	5772
1991	88727	2083	0	54671	70808	91693	0	10701	11243
1992	79286	0	0	152152	134263	20129	17289	48569	5147
1993	81637	0	0	154337	0	0	10557	0	0
1994	103839	0	0	172585	0	45350	25950	0	6436
1995	68575	0	0	144739	392	74766	47660	16786	13741
1996	104295	1139	3473	164051	156	75385	76393	23063	11199
1997	106847	275	0	184741	109	144489	43859	11760	11760
1998	108187	2790	2974	162821	62	190555	26595	8899	4522
1999	44845	228	1136	84227	10095	51065	22634	1875	8922
2000	47085	304	67	71413	9960	97697	26040	0	512
2001	26124	2787	1304	84559	27431	102235	15985	447	8447
2002	38042	4583	2362	75151	31360	85824	11155	367	6250
2003	24486	8205	1975	94988	36965	102742	12251	0	7821
2004	19258	6652	1520	78073	32282	88192	8822	323	5863
2005	22949	2938	0	67137	10003	921	7332	0	265

Table 2.8a—Length frequencies of Pacific cod in the pre-1989 trawl fishery by year, period, and length bin.

		Length Bin																								
Yr.	Per.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1974	1	0	0	0	0	0	0	0	0	0	1	4	0	7	9	13	8	5	1	2	1	1	4	1	1	0
1974	3	0	0	0	0	0	0	0	0	0	0	1	3	13	16	39	19	3	4	1	0	0	0	0	0	0
1975	1	0	0	0	0	0	0	0	4	10	16	19	20	33	31	29	30	30	15	9	3	0	2	2	0	0
1975	3	0	0	0	0	0	0	0	1	2	3	1	1	1	0	2	2	3	16	13	11	0	0	1	1	0
1977	1	0	0	0	0	0	0	0	3	12	29	15	8	11	21	23	41	29	16	11	4	1	3	0	0	0
1977	2	0	0	0	0	0	0	0	0	2	3	15	24	41	79	81	76	75	56	39	12	5	3	4	0	0
1977	3	0	0	0	0	0	0	0	0	1	1	4	3	1	0	0	0	0	0	0	0	0	0	0	0	0
1978	1	0	0	0	1	1	1	1	2	5	22	29	88	233	112	44	32	36	15	11	9	1	1	2	0	0
1978	3	0	0	0	0	0	6	35	79	37	21	19	5	62	387	999	882	337	159	81	37	13	2	0	0	0
1979	1	0	0	0	0	0	2	1	21	46	94	206	319	346	100	149	161	152	48	11	4	5	1	1	0	0
1979	3	0	0	0	0	0	0	0	3	5	24	74	150	220	78	38	47	58	31	14	4	0	0	0	1	1
1980	1	0	0	0	0	0	0	1	10	34	84	186	295	462	192	49	19	14	8	3	1	1	0	0	0	0
1980	2	0	0	0	0	0	0	0	0	0	0	0	0	1	16	45	8	3	0	0	0	0	0	0	0	0
1980	3	0	0	0	0	0	0	0	1	0	0	9	17	37	79	70	55	32	8	9	6	3	0	1	0	0
1981	1	0	0	0	0	0	0	0	0	0	0	0	8	28	43	34	16	3	0	0	0	0	0	0	0	0
1981	3	0	0	0	0	0	0	0	2	1	0	3	8	26	122	336	373	301	194	120	32	13	7	2	0	0
1982	1	0	0	0	0	0	1	1	4	21	22	9	13	48	61	94	133	84	69	20	8	3	1	0	0	0
1982	2	0	0	0	0	0	0	0	0	0	1	1	7	21	14	21	41	43	33	16	13	4	6	4	1	0
1982	3	0	0	0	0	0	0	1	0	0	1	4	27	70	143	215	196	302	346	215	90	18	9	5	1	0
1983	1	0	0	0	0	0	5	20	99	286	284	275	467	1113	1272	1978	2477	1982	1193	584	202	72	35	22	13	7
1983	2	0	0	0	0	0	1	0	1	3	10	4	7	31	95	204	289	249	187	85	30	11	8	6	7	3
1983	3	0	0	0	0	1	15	24	26	15	8	35	205	421	508	1451	1999	2487	2441	2235	1563	767	284	66	21	5
1984	1	0	1	1	1	0	7	121	251	222	132	66	148	439	503	758	1394	2027	1873	1278	639	263	96	16	9	1
1984	2	0	1	0	0	5	18	14	5	10	55	93	118	241	284	403	612	638	620	481	411	313	110	42	7	1
1984	3	0	0	0	0	0	7	21	15	114	434	370	188	137	124	254	396	576	614	483	376	224	99	32	13	0
1985	1	0	0	2	0	4	0	2	39	116	262	733	1768	2246	1088	1415	2474	5067	5635	4340	2649	1402	608	229	69	23
1985	2	0	0	0	0	0	0	0	3	24	77	70	119	425	356	116	59	70	88	73	35	20	8	9	3	1
1985	3	0	0	0	0	0	0	0	1	0	9	79	170	533	322	195	126	288	424	374	296	152	78	4	0	0
1986	1	0	4	16	8	34	62	118	249	636	761	683	788	2229	3564	3293	2108	2647	3498	3377	2446	1346	456	168	58	17
1986	2	0	0	0	0	0	0	7	4	2	4	5	9	26	95	130	195	285	481	352	128	48	30	8	4	0
1986	3	0	0	1	0	0	0	2	1	15	17	28	26	86	169	288	405	520	406	265	136	93	59	22	4	5
1987	1	0	0	3	13	15	58	194	446	516	640	1250	2235	4300	3164	3663	6190	6238	5028	4338	3669	2326	1255	510	234	75
1987	2	0	0	0	0	1	1	2	5	9	6	10	29	135	241	422	837	1294	1344	889	574	397	252	133	68	25
1987	3	0	0	0	0	0	0	0	0	7	13	68	76	263	1095	1809	2177	2736	3204	2732	2087	1946	1549	802	306	53
1988	1	1	0	1	1	6	30	93	605	1533	2081	2311	4634	11994	11361	10890	9690	10862	13124	11333	6319	3330	1855	913	380	106
1988	3	0	0	0	0	0	0	0	0	5	0	13	52	257	326	284	348	348	373	332	305	166	56	20	6	6

Table 2.8b–Length frequencies of Pacific cod in the 1989-1999 trawl fishery by year, period, and length bin.

		Length Bin																								
Yr.	Per.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1989	1	0	0	3	3	1	0	29	217	497	799	721	961	3128	4368	4678	5713	7070	8599	8291	6310	3853	1882	917	391	144
1989	2	0	0	0	0	0	0	0	0	1	0	4	3	20	68	109	136	142	79	39	9	1	0	1	0	0
1989	3	0	0	0	0	1	6	7	13	32	53	49	33	90	54	36	83	92	88	22	6	4	0	0	0	0
1990	1	0	0	3	4	14	85	312	710	953	888	715	539	1148	2576	4417	7339	9969	10306	9376	6405	4195	2266	1280	480	163
1990	2	0	0	0	0	0	0	0	2	2	6	6	17	106	377	772	1048	1631	1566	1623	1221	655	457	206	80	32
1990	3	0	0	0	0	0	0	0	0	1	2	14	42	13	30	17	16	49	17	19	16	10	0	2	0	2
1991	1	0	1	5	6	15	71	452	1230	1329	1232	1288	1713	5172	6133	6560	9202	12298	12683	10962	7771	5103	2937	1517	766	281
1991	2	1	0	1	1	2	2	7	9	16	32	25	27	103	129	216	251	300	319	219	200	136	62	18	1	6
1992	1	0	3	9	15	21	67	200	631	1310	1664	2488	4704	9607	7198	6648	6782	8239	8016	7777	5712	3853	2326	1291	517	208
1993	1	0	0	5	8	23	56	254	1164	1666	1780	4496	7742	11709	10367	9951	7408	5314	4343	3901	3540	3128	2163	1472	806	341
1994	1	0	1	5	5	24	106	610	2149	3791	3227	1938	2981	9909	14285	14434	11718	11710	9933	6337	4075	2739	1764	1161	623	314
1995	1	0	0	12	28	46	160	306	448	495	707	2597	5806	9110	5979	7066	8171	8721	7021	4381	2782	1824	1195	772	540	408
1996	1	1	6	13	25	29	51	382	1066	1319	1118	1145	2429	8755	14699	13711	9877	10959	11919	9647	6868	4308	2875	1607	911	575
1996	2	0	0	0	0	0	0	2	2	5	10	11	35	112	164	186	106	125	97	160	107	16	0	0	1	0
1996	3	0	0	0	0	0	0	1	0	3	1	13	51	132	149	275	322	292	287	305	436	454	388	220	104	40
1997	1	1	4	17	80	97	65	326	1261	2372	2398	1778	2027	7423	8553	11653	16352	16489	12167	7909	5444	4105	2800	1846	1060	620
1997	2	0	1	0	4	5	1	4	4	8	8	12	13	31	42	38	34	20	24	15	8	2	0	0	1	0
1998	1	0	1	7	4	7	114	744	1464	1423	1113	969	1398	5031	6020	6694	10192	14965	16533	10659	5972	3531	2880	2293	1631	1107
1998	2	0	0	0	0	1	0	0	1	31	61	71	47	110	242	298	270	195	125	83	36	12	9	5	10	6
1998	3	0	0	0	0	0	0	1	2	3	12	37	60	135	172	249	177	190	211	258	270	160	74	68	46	22
1999	1	4	0	1	6	5	10	108	421	412	382	1039	2515	5006	3143	3270	3992	5218	5560	4722	3617	2327	1295	818	592	382
1999	2	0	0	0	0	0	0	0	0	0	0	1	5	31	31	32	30	21	9	15	12	15	10	5	6	5
1999	3	0	0	0	0	0	0	0	2	1	0	2	18	51	114	164	145	144	121	96	88	82	53	36	14	5

Table 2.8c—Length frequencies of Pacific cod in the post-1999 trawl fishery by year, period, and length bin.

		Length Bin																								
Yr.	Per.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2000	1	0	0	0	2	2	7	63	187	173	236	559	1075	3035	4364	4870	4763	4839	5349	4673	3869	3230	2655	1546	952	636
2000	2	0	0	0	0	0	0	1	4	2	4	13	18	41	76	67	34	22	8	5	6	2	1	0	0	0
2000	3	0	0	0	0	0	0	0	0	0	0	0	0	3	13	20	12	8	6	3	0	1	1	0	0	0
2001	1	0	0	2	1	3	4	22	43	111	176	112	173	922	1483	2119	3376	4045	4026	2853	2193	1618	1195	840	531	276
2001	2	0	0	5	12	10	14	5	10	23	57	93	79	212	506	433	394	352	247	137	62	58	31	30	15	2
2001	3	0	0	0	0	0	1	2	8	12	8	21	33	80	109	200	199	202	175	109	68	33	15	14	10	5
2002	1	0	0	0	6	12	26	79	333	541	550	535	642	1780	2107	2215	3692	5123	5676	4771	3635	2621	1579	952	736	431
2002	2	0	0	0	6	8	3	12	68	201	263	306	288	417	596	747	529	399	253	195	147	69	42	20	10	4
2002	3	0	0	0	0	0	0	0	1	9	9	60	141	240	249	339	259	229	236	205	180	114	52	25	11	3
2003	1	0	0	2	4	1	2	5	82	266	333	355	647	1784	1864	2063	2746	3700	4237	3045	1798	895	379	170	78	30
2003	2	0	1	0	1	2	3	9	24	44	141	217	266	683	1106	1035	1046	1069	886	704	509	281	116	37	18	7
2003	3	0	0	0	0	0	0	0	0	0	1	7	31	94	190	200	221	225	246	237	232	156	92	35	7	1
2004	1	0	1	1	0	1	0	4	56	216	332	316	282	1295	2226	2490	2955	2947	2331	1575	998	535	339	197	113	48
2004	2	0	0	2	4	1	12	57	106	103	93	106	154	301	582	730	791	734	665	623	586	461	290	169	66	16
2004	3	0	0	0	0	0	0	0	0	0	0	3	14	55	103	198	169	134	133	164	219	161	94	61	11	1
2005	1	0	0	0	1	9	10	15	108	255	339	298	277	954	1579	2362	3351	4138	3778	2360	1496	809	466	220	90	34
2005	2	0	0	0	0	0	0	0	5	10	26	43	65	113	199	270	295	321	367	383	339	234	151	66	38	13

Table 2.9a—Length frequencies of Pacific cod in the pre-1989 longline fishery by year, period, and length bin.

		Length Bin																								
Yr.	Per	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1978	1	0	0	0	0	0	0	0	0	1	4	23	124	623	812	435	269	216	160	110	58	36	7	7	0	0
1978	2	0	0	0	0	0	0	0	0	0	1	7	40	240	574	1226	994	716	566	330	133	44	12	2	1	0
1978	3	0	0	0	0	0	0	0	0	0	0	2	0	62	366	736	788	306	124	66	35	19	8	2	0	0
1979	1	0	0	0	0	0	0	0	8	83	377	683	436	375	1303	2454	2711	1575	679	380	208	87	36	8	7	0
1979	2	0	0	0	0	0	0	0	0	2	14	49	90	155	102	327	646	660	315	86	43	17	5	3	0	0
1979	3	0	0	0	0	0	0	0	0	0	2	10	47	233	249	174	387	683	599	216	41	10	9	2	0	0
1980	1	0	0	0	0	0	0	0	0	5	15	66	212	591	604	320	182	199	244	111	36	11	4	0	0	0
1980	2	0	0	0	0	0	0	0	0	0	0	1	29	169	334	293	185	148	140	67	17	4	2	0	0	0
1980	3	0	0	0	0	0	0	0	0	0	0	1	18	235	558	679	652	350	194	138	76	25	5	0	1	0
1981	1	0	0	0	0	5	18	7	7	10	0	18	48	285	503	453	340	198	153	89	70	36	9	4	0	0
1981	2	0	0	0	0	0	0	0	0	2	1	8	29	88	160	265	292	228	108	35	32	24	3	1	0	0
1981	3	0	0	0	0	0	0	0	0	0	0	0	2	8	86	230	318	300	220	89	29	15	2	0	1	0
1982	1	0	0	0	0	0	0	0	1	1	14	22	30	215	381	520	550	468	298	167	100	78	47	13	3	2
1982	2	0	0	0	0	0	0	0	0	0	9	43	17	102	208	164	211	164	133	80	48	11	7	3	3	0
1982	3	0	0	0	0	0	0	0	1	0	1	15	35	107	270	512	830	1195	1101	639	240	82	35	9	4	2
1983	1	0	0	0	0	0	0	0	1	3	21	51	178	1231	1673	2160	2944	3606	3254	2018	876	390	220	117	48	9
1983	2	0	0	0	0	0	0	0	0	1	4	18	24	118	414	454	580	676	704	520	368	154	55	19	10	0
1983	3	0	0	0	0	0	0	1	0	0	0	4	28	129	459	1163	1262	1550	1779	1565	993	477	148	37	9	6
1984	1	0	0	0	0	0	1	0	4	11	21	22	20	191	414	614	1188	1473	1370	833	400	177	60	31	20	3
1984	2	0	0	0	0	0	2	0	0	2	3	10	8	54	232	468	960	1290	1095	774	524	374	158	36	11	3
1984	3	0	0	0	0	0	0	1	2	12	53	250	643	1558	2738	6857	12095	15376	15438	12475	8243	4156	1555	465	143	43
1985	2	0	0	0	0	0	0	0	0	0	1	3	25	221	348	177	346	628	849	710	526	392	216	96	21	2
1985	3	0	0	0	0	0	1	0	0	5	28	167	756	5832	16308	14473	11108	18384	25332	19838	11750	6227	2938	1006	252	64
1986	1	0	0	0	0	0	0	0	7	23	51	84	278	1093	1464	1354	1181	2186	3783	3595	2082	911	360	107	26	3
1986	2	0	0	0	0	0	0	0	0	0	0	0	0	0	19	29	47	23	21	32	14	9	3	3	0	0
1986	3	0	0	0	0	0	0	0	0	0	18	154	610	2194	5080	14156	23223	20331	10705	10312	8875	4920	2286	869	324	85
1987	1	0	0	0	0	0	0	0	1	10	38	291	983	3411	3420	5818	10732	12540	10019	9453	7603	3871	1490	422	145	26
1987	3	0	0	0	3	0	0	0	2	7	26	130	511	4041	17126	27487	22822	24411	26687	19727	10159	6334	3638	1480	399	134

Table 2.9b—Length frequencies of Pacific cod in the 1989-1999 longline fishery by year, period, and length bin.

		Length Bin																								
Yr.	Per	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1990	1	0	0	0	0	0	0	0	0	0	0	4	12	163	784	1700	2796	3536	3080	2490	1599	1216	728	480	219	93
1990	2	0	0	0	0	0	0	6	6	24	56	136	238	794	2391	5893	10108	12945	12636	10237	7314	5084	3262	2200	889	315
1990	3	0	0	0	0	0	0	1	3	1	12	18	56	348	1644	5170	9453	11864	11121	8939	6057	3593	2102	1291	598	279
1991	1	0	0	0	0	0	0	0	5	14	30	114	306	1052	2487	5075	8929	11159	9547	6917	4040	2444	1331	780	311	130
1991	2	0	0	0	0	0	0	0	5	9	19	35	143	773	2130	4733	8310	10823	12060	10930	8769	6004	3203	1778	793	291
1991	3	0	0	0	1	3	18	33	39	62	127	207	467	1723	4038	7030	10634	13041	14086	13443	10791	7589	4290	2527	1104	440
1992	1	0	0	0	2	0	3	5	42	90	312	1253	3300	10451	14863	15640	19126	23004	20775	15837	11594	7556	4380	2455	1057	407
1992	2	0	0	0	0	3	2	3	21	66	174	574	1325	6719	13151	13754	15857	17833	16704	14043	11802	8990	6331	4035	2045	831
1992	3	0	0	0	0	0	0	0	1	6	19	52	154	765	2375	2564	2390	2741	2404	1939	1595	1267	888	565	298	106
1993	1	0	0	1	0	1	6	16	76	186	450	1482	3328	10312	20462	27089	23370	17302	14383	12020	9965	6845	3850	1953	926	314
1994	1	0	0	0	3	3	12	23	40	91	223	551	1472	7088	17414	29142	38186	32928	19177	9869	6051	4280	3011	1766	930	325
1994	3	0	0	0	0	0	0	2	8	12	57	145	268	952	3070	5831	8261	9569	7327	4226	2341	1425	914	505	296	141
1995	1	0	0	0	2	5	6	13	24	60	186	1059	3031	8219	14024	23789	30478	28823	18233	8432	3841	1961	1172	730	445	206
1995	2	0	0	0	0	0	0	0	0	0	1	0	3	10	33	55	79	56	29	37	38	27	15	9	0	0
1995	3	0	0	1	0	0	1	2	21	25	50	219	522	2929	7080	8279	9857	12273	11397	8717	5585	3365	2040	1402	714	287
1996	1	0	0	0	0	0	0	1	20	73	192	604	1794	9116	19703	26399	29777	28680	21120	12783	6741	3465	1691	992	518	382
1996	2	0	0	0	0	0	0	0	0	0	0	0	0	9	27	23	27	17	15	15	14	6	3	0	0	0
1996	3	0	0	0	0	0	1	0	4	15	83	182	404	1626	5549	11617	14477	11224	8332	7296	5950	4217	2391	1149	562	306
1997	1	0	0	0	0	0	1	5	18	92	224	571	1700	8606	17788	30652	40069	35267	21243	12004	7165	4417	2557	1322	651	389
1997	2	0	0	0	0	0	0	0	0	0	0	1	1	4	6	18	18	15	16	5	8	6	4	4	3	0
1997	3	0	0	1	2	3	13	20	89	160	288	621	1673	4814	9408	15198	20854	26965	25031	17322	8992	6074	3767	1977	853	364
1998	1	0	0	0	0	1	9	19	94	224	414	957	2524	8417	13159	18857	27872	30580	24229	13821	7243	4858	3787	2748	1747	1261
1998	2	0	0	0	0	0	0	0	0	0	1	1	6	22	4	9	7	4	1	2	3	0	2	0	0	0
1998	3	1	0	0	1	32	23	46	45	93	370	1928	4087	9736	15515	22466	26645	30947	28225	21358	13610	7212	3900	2469	1211	635
1999	1	0	0	0	2	2	0	4	22	60	220	1263	3731	8701	8787	10336	12449	12238	10724	7083	4170	2019	1037	624	408	347
1999	2	0	0	0	0	0	0	0	0	6	13	44	135	981	1548	1315	1398	1400	1230	816	573	328	175	77	42	14
1999	3	1	0	0	0	0	1	10	27	61	115	371	707	3684	7968	7048	6468	6890	6175	4308	3091	1886	1110	554	359	231

Table 2.9c—Length frequencies of Pacific cod in the post-1999 longline fishery by year, period, and length bin.

		Length Bin																								
Yr.	Per.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2000	1	2	0	0	0	0	1	5	16	50	189	679	1627	6534	10526	11488	9991	8549	6638	4465	3133	2504	1923	1339	957	797
2000	2	0	0	0	0	0	0	0	0	0	4	10	27	248	654	1256	1910	1616	1240	891	701	500	397	250	156	100
2000	3	1	8	0	0	0	1	3	7	15	71	431	1300	4358	10130	16501	21226	16982	10164	6387	4077	2569	1573	881	569	443
2001	1	1	0	0	0	2	2	5	27	117	363	581	1283	5348	10260	14341	16442	13783	8606	4957	2958	1878	1393	955	705	552
2001	2	0	0	0	0	0	0	2	10	26	103	211	407	1449	3133	4343	4736	4615	3548	1825	1100	597	408	322	332	264
2001	3	0	0	0	1	4	0	5	21	56	236	1040	2147	6079	10320	16069	18724	18097	13810	6921	3436	1789	1248	960	679	593
2002	1	1	2	5	5	7	14	20	90	198	346	1104	2778	6505	7619	10662	14937	13802	9000	4165	1962	900	502	330	124	73
2002	2	0	0	0	0	1	2	3	27	74	189	328	637	2568	4552	5151	5247	5129	3579	2091	942	415	229	114	68	14
2002	3	2	0	0	0	0	2	17	49	164	428	1068	2283	7508	12276	13901	13729	12909	10164	5968	2954	1297	589	261	135	120
2003	1	0	0	2	0	3	1	9	40	233	528	1469	3627	10878	15728	16306	15084	13262	9552	4839	2150	775	312	123	53	14
2003	2	0	0	0	0	0	1	1	5	10	54	185	571	2478	5601	7083	6687	5653	4235	2311	1204	532	214	102	31	7
2003	3	1	0	0	0	0	0	0	4	23	91	269	1181	6401	13746	18801	18771	16306	12049	7757	4265	1892	740	287	116	42
2004	1	0	1	0	0	2	0	2	8	55	155	330	954	4834	10937	16754	18365	12760	6674	3390	1713	703	268	112	43	13
2004	2	0	0	0	0	0	1	0	0	10	20	46	198	1044	2832	5247	6471	6058	4522	2648	1749	873	383	122	48	10
2004	3	1	0	0	1	1	3	4	22	49	162	366	929	3948	8110	12938	17249	16959	12732	7120	4017	2145	938	356	111	31
2005	1	0	0	0	1	0	2	5	27	84	199	528	1157	3953	6466	9408	13667	14874	10195	3945	1517	699	279	100	24	7
2005	2	0	0	0	0	1	0	0	3	6	10	47	75	331	658	971	1301	1659	1741	1364	901	488	302	108	32	5
2005	3	0	0	0	0	0	0	0	0	0	0	0	2	25	54	94	127	136	158	127	95	55	23	15	9	1

Table 2.10a—Length frequencies of Pacific cod in the 1989-1999 pot fishery by year, period, and length bin.

Yr.	Per	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
		Length Bin																								
1990	2	0	0	0	0	0	0	0	0	0	0	0	1	7	42	74	141	230	293	220	229	138	81	45	3	2
1990	3	0	0	0	0	0	0	0	0	0	0	0	1	3	10	116	512	1149	1146	1360	701	391	260	109	11	3
1991	2	0	0	0	0	0	0	0	0	0	0	0	0	39	240	572	1106	1700	2050	1874	1636	875	414	155	35	5
1991	3	0	0	0	0	0	0	0	0	0	0	0	6	29	163	406	790	1444	2084	2236	1810	1218	637	290	101	29
1992	1	0	0	0	0	0	1	0	1	0	8	7	24	174	380	731	1875	3807	3583	2710	1776	1160	590	324	99	39
1992	2	0	0	0	0	0	0	1	2	5	36	103	438	2186	3592	4075	5205	6914	7708	7212	5139	3268	1601	710	261	113
1992	3	0	0	0	0	0	0	0	0	2	22	73	145	590	869	749	599	526	406	327	306	200	151	79	48	55
1993	1	0	0	0	0	0	0	0	0	0	0	8	28	320	824	1448	1968	1869	1621	1062	640	384	233	93	41	18
1994	1	0	0	0	0	0	0	0	0	0	1	19	125	727	2791	4384	4660	4567	3529	2371	1284	706	409	238	112	27
1994	3	0	0	0	0	0	0	0	0	5	3	10	25	152	576	1095	1255	1050	808	601	364	229	136	71	39	17
1995	1	0	0	0	0	0	0	0	0	1	4	45	242	1203	3094	6944	10101	9099	6435	3950	2408	1608	1394	826	222	84
1995	2	0	0	0	0	0	0	0	0	0	0	5	56	443	841	1540	2499	2682	2128	1816	1425	1139	1007	520	449	236
1995	3	0	0	0	0	0	0	0	0	0	1	0	16	275	821	1444	2240	2490	2142	1563	1158	787	449	201	125	29
1996	1	0	0	0	0	0	3	5	11	14	39	89	268	2272	6731	10936	13049	13395	10997	7115	4724	2883	1910	1123	588	241
1996	2	0	0	0	0	0	0	0	0	1	1	6	43	389	1293	2879	3807	3552	2788	2147	1939	1517	1126	771	513	291
1996	3	0	0	0	0	0	0	0	0	0	0	3	12	174	464	953	1766	1923	1526	1088	991	929	668	400	218	84
1997	1	0	0	0	0	1	0	0	1	3	15	38	82	647	2100	5113	9620	10616	6855	3690	1963	1239	838	530	311	197
1997	2	0	0	0	0	0	0	0	1	0	1	7	22	164	454	973	1685	2434	2523	1440	704	477	393	270	143	69
1997	3	0	0	0	0	0	0	0	1	0	1	7	22	164	454	973	1685	2434	2523	1440	704	477	393	270	143	69
1998	1	0	0	0	0	1	0	0	0	2	4	17	93	695	1363	2166	4743	6257	5386	3157	1369	579	372	213	118	60
1998	2	0	0	0	0	0	0	0	0	0	0	5	12	159	524	934	1372	1824	1709	1051	520	280	210	131	111	57
1998	3	0	0	0	0	0	0	0	1	0	3	8	10	70	257	405	605	730	788	587	396	247	147	130	72	66
1999	1	0	0	0	0	0	0	1	2	2	6	17	106	918	1497	2389	3677	3882	3557	2484	1586	958	656	392	332	172
1999	2	0	0	0	0	0	0	0	0	0	0	2	7	58	123	151	239	239	257	198	170	148	116	72	51	44
1999	3	0	0	0	0	0	0	0	0	4	12	21	53	305	793	1153	1122	1255	1086	835	696	585	442	249	202	109

Table 2.10b—Length frequencies of Pacific cod in the post-1999 pot fishery by year, period, and length bin.

		Length Bin																								
Yr.	Per.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2000	1	0	0	0	0	0	0	0	1	2	2	12	112	934	2545	4019	4085	3753	3482	2412	1715	1125	882	487	256	216
2000	3	0	0	0	0	0	0	0	0	0	1	1	3	39	87	134	149	62	25	8	0	2	1	0	0	0
2001	1	4	0	1	0	0	0	0	0	0	0	3	13	234	796	2200	4015	4021	2277	1046	485	316	232	168	78	96
2001	2	0	0	0	0	0	0	0	0	0	0	0	0	0	12	45	77	103	93	61	33	5	7	4	6	1
2001	3	0	0	0	0	0	0	2	2	1	4	4	14	155	618	1313	1543	1768	1322	674	438	267	156	93	48	25
2002	1	0	0	0	0	0	0	0	0	0	1	4	16	131	605	1564	2847	2848	1789	768	297	134	78	39	20	14
2002	2	0	0	0	0	0	0	0	0	0	0	1	2	3	20	45	72	65	62	41	32	9	12	2	0	1
2002	3	0	0	0	0	0	1	0	0	0	0	5	26	165	580	1244	1352	1026	728	485	314	144	107	43	19	11
2003	1	0	0	0	0	0	0	0	2	3	3	6	54	267	766	1391	2203	2788	2360	1328	655	259	97	41	19	9
2003	3	0	0	0	0	0	0	0	0	1	0	2	19	236	920	1472	1403	1227	951	607	449	291	153	60	26	4
2004	1	0	0	0	0	0	0	0	0	0	0	1	15	253	895	1493	1870	1709	1185	668	375	188	105	43	17	5
2004	2	0	0	0	0	0	0	0	0	0	0	0	0	2	22	53	56	60	46	32	15	16	18	3	0	0
2004	3	0	0	0	0	0	0	1	2	2	2	4	18	105	510	1039	1101	904	660	420	389	330	188	127	47	14
2005	1	0	0	0	0	0	0	0	0	1	0	6	13	119	426	1088	1709	1600	1117	554	309	180	118	62	26	4
2005	3	0	0	0	0	0	0	0	0	0	0	0	0	1	13	43	65	49	28	24	17	7	5	12	1	0

Table 2.11—Length frequencies of Pacific cod in the EBS shelf bottom trawl survey by year (all surveys take place in period 2). Numbers shown are survey estimates of population numbers at length, rescaled so that the sum equals the total size of the actual survey length sample.

		Length Bin																								
Yr.	Per	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1979	2	0	5	44	186	374	457	694	1764	2393	1884	1171	618	202	70	44	51	29	8	0	3	1	1	0	0	0
1980	2	0	6	85	241	82	42	224	687	929	1320	1542	2062	1364	893	333	100	33	31	19	6	2	0	0	0	0
1981	2	0	20	156	330	278	32	100	330	653	724	511	1063	1396	1746	1215	812	398	156	39	27	13	1	0	0	0
1982	2	17	89	216	139	37	28	131	405	772	757	412	811	1243	1324	1299	1196	865	474	202	84	27	8	3	0	0
1983	2	365	1309	1234	605	143	30	131	347	532	386	214	635	1171	1346	1405	1171	920	675	325	146	29	18	4	1	0
1984	2	52	107	80	146	306	924	1674	1730	1041	472	243	353	438	584	859	950	865	580	388	184	101	44	12	1	0
1985	2	149	549	967	1508	1695	653	302	611	919	979	1187	2016	1376	662	476	544	689	677	496	250	117	41	17	7	0
1986	2	91	286	320	99	75	452	1163	1257	1040	711	359	396	573	869	776	406	268	296	244	171	79	48	13	8	0
1987	2	18	72	248	385	258	179	413	847	729	580	600	1231	1089	768	551	604	581	378	193	151	61	45	15	6	0
1988	2	9	53	80	91	109	236	282	393	666	627	493	987	1102	1310	1086	833	559	414	293	234	75	33	28	7	0
1989	2	17	137	316	224	69	37	92	102	147	350	347	565	709	1218	1308	1138	941	800	632	326	234	146	87	59	0
1990	2	203	491	689	357	132	124	263	303	323	277	174	160	169	224	349	408	276	262	170	123	82	33	25	10	1
1991	2	141	408	447	381	228	262	595	867	912	611	349	249	259	327	260	226	211	181	108	107	49	20	22	7	1
1992	2	18	468	451	565	514	455	891	1092	872	560	462	889	699	564	244	233	186	108	101	91	54	38	30	15	1
1993	2	114	924	1087	981	677	213	247	614	847	666	489	845	842	665	398	267	230	85	62	49	36	21	24	15	6
1994	2	18	145	291	361	327	446	957	1924	2082	1121	443	685	1051	964	1058	920	565	288	92	46	33	60	15	22	8
1995	2	29	74	135	208	77	172	460	691	580	705	1064	1575	1017	617	434	484	326	253	133	84	41	27	18	9	3
1996	2	14	65	164	198	110	103	357	699	677	526	499	744	1477	1404	908	499	288	237	148	109	71	25	16	7	3
1997	2	91	472	601	728	507	140	215	481	628	451	407	399	918	809	842	583	436	215	105	60	40	26	10	4	1
1998	2	30	262	334	74	46	311	1151	1837	1396	655	379	367	659	458	378	391	333	244	132	64	33	29	9	10	1
1999	2	71	335	286	113	141	415	760	874	667	719	1169	1648	1854	768	493	447	337	252	130	89	62	37	24	7	2
2000	2	175	918	1310	505	54	141	488	785	604	564	749	958	1720	1419	894	537	266	188	99	79	57	33	19	3	0
2001	2	95	640	1815	2110	1011	407	903	1994	2550	1618	706	486	1193	1278	1080	819	515	257	123	71	34	22	14	4	5
2002	2	31	192	374	352	105	207	662	1456	1446	1004	791	1216	1579	880	611	546	368	209	104	49	19	16	15	3	2
2003	2	19	283	635	774	682	489	182	255	705	837	974	1188	1969	1213	767	513	338	259	141	86	35	14	2	1	0
2004	2	24	275	483	562	318	218	484	729	930	978	711	578	805	926	845	715	475	286	211	111	82	34	15	5	4
2005	2	5	152	589	890	1016	1051	487	418	576	728	652	631	859	702	518	525	490	354	288	179	102	46	21	7	0

Table 2.12—Age composition estimates from the 1996-2003 EBS shelf bottom trawl surveys (expressed as numbers per 10,000).

Age	1996	1997	1998	1999	2000	2001	2002	2003
1	41	2531	705	757	2330	2911	832	1744
2	2305	1805	4526	2011	1149	2365	1860	1590
3	2466	1696	2011	3111	1656	1966	3085	2467
4	3564	1572	1132	2377	2447	900	2437	2143
5	940	1196	586	791	1544	877	741	1183
6	540	876	593	542	588	673	573	400
7	144	221	283	269	107	227	382	282
8	0	79	140	98	118	54	64	146
9	0	9	22	36	28	14	18	32
10	0	10	0	0	26	9	6	3
11	0	6	2	7	7	6	0	3
12+	0	0	0	0	0	1	1	7

Table 2.13—Biomass, standard error, 95% confidence interval (CI), and population numbers of Pacific cod estimated by NMFS' annual bottom trawl survey of the EBS shelf. All figures except population numbers are expressed in metric tons. Population numbers are expressed in terms of individual fish.

Year	Biomass	Standard Error	Lower 95% CI	Upper 95% CI	Numbers
1979	754,314	97,844	562,539	946,089	1,530,429,650
1980	905,344	87,898	733,063	1,077,624	1,084,147,540
1981	1,034,629	123,849	791,885	1,277,373	794,619,624
1982	1,020,550	73,392	876,701	1,164,399	583,715,089
1983	1,176,305	121,606	937,958	1,414,651	725,351,369
1984	1,001,940	64,127	876,251	1,127,629	636,948,300
1985	961,050	51,453	860,203	1,061,896	800,070,473
1986	1,134,106	71,813	993,353	1,274,858	843,460,794
1987	1,142,450	71,439	1,002,430	1,282,468	754,269,021
1988	959,544	76,284	810,028	1,109,060	509,336,483
1989	960,436	69,157	824,888	1,095,984	339,719,445
1990	708,551	53,728	603,245	813,857	435,856,535
1991	532,590	41,678	450,902	614,279	496,841,261
1992*	546,707	45,754	457,030	636,383	577,416,832
1993	690,524	54,934	582,853	798,196	851,866,426
1994	1,368,109	254,435	869,416	1,866,802	1,237,760,162
1995	1,003,046	92,677	821,400	1,184,692	757,576,445
1996	890,793	120,522	652,160	1,129,426	609,304,214
1997	604,881	69,250	466,382	743,380	487,429,700
1998	534,141	42,942	449,116	619,166	514,321,475
1999	583,259	50,622	483,028	683,490	500,692,872
2000	528,466	43,037	443,253	613,679	481,358,109
2001	833,272	76,267	680,739	985,805	984,379,812
2002	620,520	69,046	482,428	758,612	567,926,526
2003	605,681	63,601	478,479	732,882	510,187,323
2004	596,988	35,135	527,421	666,556	424,265,173
2005	603,788	43,150	517,488	690,089	452,075,840

*During the 1992 field season, 18 stations were omitted from the standard survey grid due to severe weather and vessel problems. In 1989, 1990, and 1991, these 18 stations represented, on average, 2.2% and 2.8% of the total Pacific cod biomass and numbers, respectively. The 1992 point estimates and confidence interval shown above have been adjusted upward proportionately.

Table 2.14—Length frequencies of Pacific cod in the EBS slope bottom trawl survey by year (all surveys take place in period 2). Numbers shown are survey estimates of population numbers at length, rescaled so that the sum equals the total size of the actual survey length sample.

		Length Bin																								
Yr.	Per.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2002	2	0	0	0	0	0	0	0	0	1	0	5	18	69	105	86	62	55	39	21	7	1	0	0	0	0
2004	2	0	0	0	0	0	0	0	0	0	1	1	2	32	94	114	128	93	44	10	7	3	2	0	0	0

Table 2.15—Pacific cod commercial fishery length sample sizes used in the multinomial distribution. (These values correspond to the square roots of the true sample sizes shown in Table 2.5.)

	Trawl Fishery			Longline Fishery			Pot Fishery		
Year	Per. 1	Per. 2	Per. 3	Per. 1	Per. 2	Per. 3	Per. 1	Per. 2	Per. 3
1974	8	0	10	0	0	0	0	0	0
1975	16	8	0	0	0	0	0	0	0
1977	15	23	3	0	0	0	0	0	0
1978	25	0	56	54	70	50	0	0	0
1979	41	0	27	107	50	52	0	0	0
1980	37	9	18	51	37	54	0	0	0
1981	11	0	39	47	36	36	0	0	0
1982	24	15	41	54	35	71	0	0	0
1983	111	35	121	137	64	98	0	0	0
1984	101	67	67	83	77	287	0	0	0
1985	174	39	55	0	68	367	0	0	0
1986	169	43	50	136	14	323	0	0	0
1987	215	82	145	265	0	406	0	0	0
1988	322	0	54	0	0	0	0	0	0
1989	242	25	26	0	0	0	0	0	0
1990	253	99	16	137	273	250	0	39	76
1991	298	46	0	234	266	303	0	103	106
1992	282	0	0	390	366	142	131	220	72
1993	286	0	0	393	0	0	103	0	0
1994	322	0	0	415	0	213	161	0	80
1995	262	0	0	380	20	273	218	130	117
1996	323	34	59	405	12	275	276	152	106
1997	327	17	0	430	10	380	209	108	108
1998	329	53	55	404	8	437	163	94	67
1999	212	15	34	290	100	226	150	43	94
2000	217	17	8	267	100	313	161	0	23
2001	162	53	36	291	166	320	126	21	92
2002	195	68	49	274	177	293	106	19	79
2003	156	91	44	308	192	321	111	0	88
2004	139	82	39	279	180	297	94	18	77
2005	151	54	0	259	100	30	86	0	16

Table 2.16—Time series of EBS Pacific cod age 3+ biomass, spawning biomass, and survey biomass as estimated by Models 1, 2, and 3 (M1, M2, and M3). The standard deviation for each estimated spawning biomass ("SB Std. Dev.") is shown for Models 2 and 3. The time series observed by the survey itself is shown on the far right ("Obs.") for comparison to model estimates. All biomass figures are in 1000s of t.

	Age 3+ Biomass			Spawning Biomass			SB Std. Dev.		Survey Biomass			
Year	M1	M2	M3	M1	M2	M3	M2	M3	M1	M2	M3	Obs.
1964		411	469		140	173	6.0	9.0				
1965		420	479		144	177	6.0	9.0				
1966		427	487		148	181	6.0	9.1				
1967		419	479		149	182	6.1	9.1				
1968		390	449		142	176	6.6	9.3				
1969		333	388		123	155	8.6	10.1				
1970		284	333		104	133	11.2	11.5				
1971		221	261		78	102	12.9	12.9				
1972		196	228		64	84	12.6	13.0				
1973		184	207		54	70	11.0	12.1				
1974		164	180		45	56	8.6	10.2				
1975		145	155		36	44	6.5	8.1				
1976		131	142		33	39	5.5	6.7				
1977		206	204		33	38	4.8	6.0				
1978	325	249	249	72	48	52	5.8	6.7				
1979	647	470	465	117	77	81	8.4	9.0	666	631	543	754
1980	1126	892	841	209	135	140	12.8	13.2	989	976	814	905
1981	1533	1187	1135	365	243	249	19.2	20.3	1173	1208	1045	1035
1982	1911	1472	1405	543	381	390	25.9	29.3	1143	1032	946	1021
1983	2084	1607	1566	685	502	518	30.5	36.9	1104	1050	1002	1176
1984	2169	1626	1625	760	568	594	32.0	41.3	1111	1098	1062	1002
1985	2261	1726	1715	773	578	615	31.1	42.8	1128	1101	1072	961
1986	2257	1674	1684	771	566	609	29.3	42.6	1132	1114	1079	1134
1987	2313	1748	1731	778	565	609	27.6	42.0	1124	1109	1063	1142
1988	2265	1707	1688	774	564	605	26.2	40.9	1013	1008	979	960
1989	2075	1548	1541	743	544	577	24.8	39.3	857	878	870	960
1990	1842	1360	1376	695	514	544	23.2	36.8	744	787	796	709
1991	1655	1214	1245	610	457	490	20.9	33.5	713	748	745	533
1992	1538	1153	1165	517	376	410	18.4	29.8	731	737	713	547
1993	1488	1137	1133	472	338	369	16.6	27.0	746	742	706	691
1994	1498	1161	1153	473	346	371	15.6	25.4	763	776	731	1368
1995	1496	1206	1180	462	355	375	15.2	24.4	719	737	692	1003
1996	1374	1118	1097	438	344	360	15.1	23.9	632	666	632	891
1997	1236	1014	1004	408	333	347	15.3	23.7	556	604	581	605
1998	1094	906	904	362	297	311	15.3	23.2	547	596	571	534
1999	1081	915	911	331	275	292	15.4	23.0	567	591	569	583
2000	1078	902	905	322	266	285	15.7	23.3	586	597	579	528
2001	1089	903	916	330	268	288	16.1	23.8	634	637	618	833
2002	1181	962	979	339	275	299	16.2	24.2	678	656	638	621
2003	1224	993	1018	352	278	305	16.2	24.6	678	639	635	606
2004	1226	954	1002	369	285	316	16.6	25.6	629	591	609	597
2005	1157	886	963	373	283	321	17.3	26.9	562	528	571	604

Table 2.17—Normalized values of the main components of the log posterior density as a function of various combinations of fixed values of the natural mortality rate *M* and the shelf bottom trawl survey catchability coefficient *Q*, with recruitment variability and the log ratio of pre-1977 median recruitment to post-1976 median recruitment fixed at the values estimated for Model 2 and all other paramters free. For the combinations shown here, the maximum log posterior density was achieved at *M*=0.2 and *Q*=2.00. Normalization was achieved by subtracting the maximum log posterior density from each value (meaning that a positive value in the table below implies a better fit to the respective component than was achieved by the overall optimum combination of *M*=0.2 and *Q*=2.00, with a negative value implying the opposite). Values shown in italic correspond to model runs in which the Hessian matrix was not positive definite.

Length Comps

	M					
Q	0.20	0.25	0.30	0.35	0.40	Ave.
0.50	93	52	1	-73	-125	-10
0.75	73	32	-50	*-88*	*-138*	-34
1.00	44	-29	-47	*-91*	*-160*	-56
1.25	-3	-25	*-52*	-103	*-182*	-73
1.50	-2	-22	-59	-120	*-205*	-82
1.75	-1	-25	*-69*	-136	*-230*	-92
2.00	0	-30	-79	-153	*-251*	-103
2.25	-1	-35	-92	*-171*	-273	-114
2.50	-3	-43	-104	*-187*	-293	-126
Ave.	22	-14	-61	-125	-206	-77

Priors

	M					
Q	0.20	0.25	0.30	0.35	0.40	Ave.
0.50	-129	-80	-41	9	16	-45
0.75	-91	-51	14	*17*	*0*	-22
1.00	-51	14	2	*0*	*-5*	-8
1.25	-5	6	*1*	-5	*-10*	-3
1.50	0	1	-3	-8	*-14*	-5
1.75	2	-1	*-6*	-12	*-18*	-7
2.00	0	-4	-10	-15	*-22*	-10
2.25	-2	-7	-13	*-18*	-27	-13
2.50	-4	-10	-16	*-22*	-32	-17
Ave.	-31	-15	-8	-6	-12	-14

Age Comps

	M					
Q	0.20	0.25	0.30	0.35	0.40	Ave.
0.50	-30	-24	-17	-3	2	-14
0.75	-22	-17	1	*6*	*-5*	-7
1.00	-13	3	-3	*-4*	*-9*	-5
1.25	-4	-1	*-3*	-6	*-14*	-6
1.50	-1	-1	-4	-10	*-19*	-7
1.75	0	-2	*-7*	-15	*-26*	-10
2.00	0	-3	-10	-19	*-31*	-13
2.25	-1	-6	-14	*-24*	-38	-16
2.50	-2	-8	-17	*-29*	-43	-20
Ave.	-8	-6	-8	-12	-20	-11

Size at Age

	M					
Q	0.20	0.25	0.30	0.35	0.40	Ave.
0.50	-20	-19	-16	-29	-33	-23
0.75	-28	-18	-30	*-35*	*-14*	-25
1.00	-26	-33	-9	*-10*	*-11*	-18
1.25	-9	-11	*-6*	-7	*-8*	-8
1.50	-5	-3	-4	-4	*-7*	-4
1.75	-2	-2	*-1*	-2	*-5*	-2
2.00	0	0	1	0	*-5*	-1
2.25	1	2	3	*1*	-4	1
2.50	3	4	3	*1*	-5	1
Ave.	-10	-9	-7	-9	-10	-9

Survey Biomass

	M					
Q	0.20	0.25	0.30	0.35	0.40	Ave.
0.50	3	5	6	6	8	6
0.75	4	5	4	*7*	*7*	6
1.00	4	0	6	*7*	*5*	4
1.25	-3	3	*6*	6	*2*	3
1.50	-1	3	6	4	*-2*	2
1.75	0	3	*4*	2	*-6*	1
2.00	0	3	3	-2	*-10*	-1
2.25	-1	2	1	*-5*	-13	-3
2.50	-1	1	-1	*-8*	-17	-5
Ave.	1	3	4	2	-3	1

Recruits

	M					
Q	0.20	0.25	0.30	0.35	0.40	Ave.
0.50	-9	6	15	22	25	12
0.75	-7	9	20	*25*	*26*	14
1.00	-4	13	20	*25*	*27*	16
1.25	-1	13	*21*	25	*27*	17
1.50	-1	14	21	26	*28*	18
1.75	0	14	*22*	26	*28*	18
2.00	0	14	22	26	*28*	18
2.25	0	15	22	*26*	28	18
2.50	0	15	22	*26*	29	18
Ave.	-2	13	21	25	27	17

Table 2.18—Estimates of Pacific cod fishing mortality rates, expressed on an annual time scale. Empty cells indicate that no catch was recorded.

	Trawl			Longline			Pot		
Year	Per. 1	Per. 2	Per. 3	Per. 1	Per. 2	Per. 3	Per. 1	Per. 2	Per. 3
1964	0.021	0.008	0.009	0.003	0.000	0.005			
1965	0.023	0.009	0.010	0.003	0.000	0.005			
1966	0.028	0.011	0.012	0.004	0.001	0.007			
1967	0.049	0.019	0.022	0.007	0.001	0.012			
1968	0.093	0.038	0.043	0.012	0.002	0.024			
1969	0.094	0.038	0.044	0.012	0.002	0.025			
1970	0.155	0.066	0.078	0.021	0.003	0.045			
1971	0.126	0.052	0.060	0.017	0.003	0.035			
1972	0.151	0.063	0.073	0.021	0.003	0.042			
1973	0.216	0.095	0.108	0.030	0.005	0.061			
1974	0.287	0.134	0.151	0.040	0.006	0.081			
1975	0.272	0.127	0.140	0.038	0.006	0.073			
1976	0.280	0.134	0.145	0.040	0.006	0.075			
1977	0.174	0.077	0.076	0.027	0.004	0.040			
1978	0.156	0.067	0.065	0.024	0.003	0.032			
1979	0.080	0.033	0.032	0.012	0.001	0.016			
1980	0.052	0.021	0.020	0.008	0.001	0.010			
1981	0.025	0.022	0.030	0.002	0.001	0.005			
1982	0.024	0.019	0.016	0.000	0.001	0.002			
1983	0.036	0.021	0.019	0.003	0.001	0.002			
1984	0.041	0.021	0.021	0.004	0.002	0.018			
1985	0.049	0.025	0.020	0.013	0.002	0.022			
1986	0.057	0.025	0.021	0.009	0.000	0.018			
1987	0.062	0.015	0.020	0.022	0.001	0.029			
1988	0.124	0.025	0.046	0.001	0.001	0.002			
1989	0.120	0.015	0.018	0.004	0.005	0.005	0.000	0.000	0.000
1990	0.102	0.011	0.010	0.013	0.018	0.020		0.001	0.000
1991	0.123	0.018	0.007	0.030	0.029	0.042	0.000	0.001	0.003
1992	0.081	0.016	0.008	0.073	0.039	0.010	0.004	0.008	0.000
1993	0.101	0.008	0.012	0.078	0.000	0.000	0.003	0.000	
1994	0.089	0.008	0.023	0.085	0.000	0.030	0.008		0.005
1995	0.125	0.012	0.016	0.095	0.000	0.043	0.018	0.006	0.005
1996	0.111	0.004	0.014	0.087	0.000	0.040	0.027	0.010	0.005
1997	0.119	0.006	0.013	0.102	0.000	0.074	0.022	0.006	0.006
1998	0.074	0.009	0.016	0.089	0.000	0.053	0.015	0.005	0.003
1999	0.079	0.006	0.006	0.099	0.004	0.046	0.017	0.002	0.004
2000	0.087	0.008	0.008	0.077	0.003	0.075	0.031		0.000
2001	0.044	0.012	0.010	0.069	0.012	0.079	0.022	0.001	0.008
2002	0.069	0.016	0.007	0.087	0.022	0.067	0.019	0.001	0.007
2003	0.063	0.017	0.005	0.090	0.019	0.071	0.027	0.000	0.011
2004	0.075	0.020	0.005	0.089	0.017	0.069	0.021	0.001	0.007
2005	0.077	0.011	0.006	0.084	0.021	0.069	0.019	0.000	0.008

Table 2.19—Estimates of Pacific cod regime-specific median recruitments and recruitment deviations. Deviations are expressed as the difference between the logarithm of annual recruitment at age 0 and the logarithm of median recruitment for the respective environmental regime.

Year	ln(Median Recruitment)	Annual Deviation
1964	11.744	-0.408
1965	11.744	-0.453
1966	11.744	-0.508
1967	11.744	-0.544
1968	11.744	-0.463
1969	11.744	-0.060
1970	11.744	0.064
1971	11.744	-0.288
1972	11.744	0.049
1973	11.744	-0.197
1974	11.744	1.553
1975	11.744	-1.147
1976	11.744	2.403
1977	13.034	1.288
1978	13.034	-0.221
1979	13.034	0.411
1980	13.034	-0.487
1981	13.034	-0.157
1982	13.034	0.989
1983	13.034	-0.678
1984	13.034	0.851
1985	13.034	-0.449
1986	13.034	-0.811
1987	13.034	-1.104
1988	13.034	0.204
1989	13.034	0.749
1990	13.034	0.067
1991	13.034	0.145
1992	13.034	0.535
1993	13.034	-0.777
1994	13.034	-0.495
1995	13.034	0.168
1996	13.034	0.457
1997	13.034	-0.311
1998	13.034	0.166
1999	13.034	0.563
2000	13.034	0.252
2001	13.034	-0.548
2002	13.034	-0.169
2003	13.034	-0.563
2004	13.034	-0.078

Table 2.20—Time series of temperature anomalies ("Temp.") and estimated shelf bottom trawl survey catchability ("*Q*").

Year	Temp.	*Q*
1979	n/a	0.818
1980	n/a	0.818
1981	n/a	0.818
1982	-0.467	0.819
1983	0.417	0.817
1984	-0.304	0.819
1985	-0.265	0.819
1986	-0.766	0.819
1987	0.606	0.817
1988	-0.239	0.819
1989	0.352	0.817
1990	-0.246	0.819
1991	0.164	0.818
1992	-0.720	0.819
1993	0.424	0.817
1994	-0.714	0.819
1995	-0.857	0.820
1996	0.807	0.817
1997	0.170	0.818
1998	0.651	0.817
1999	-1.832	0.821
2000	-0.460	0.819
2001	-0.057	0.818
2002	0.638	0.817
2003	1.145	0.816
2004	0.736	0.817
2005	0.821	0.817

Table 2.21—Estimates of Pacific cod selectivity parameters. The first column lists the eight parameters of the selectivity function: the size at which selectivity first reaches a value of 1 (“peak location”), selectivity at the minimum length represented in the data (“S(Lmin)”), the logit transform of the size corresponding to the inflection of the ascending logistic curve (“logit(infl1)”), the relative slope of the ascending logistic curve (“slope1”), the logit transform of the size corresponding to the inflection of the descending logistic curve (“logit(infl2)”), the relative slope of the descending logistic curve (“slope2”), the logit transform of selectivity at the maximum length represented in the data (“logit(S(Lmax))”), and the width of the length range at which selectivity equals 1 (“peak width”). The middle portion of the table lists the portion of the time series (“era”) to which each parameter value applies (FOR = pre-1988, DOM = 1989-1999, NEW = post-1999), for each of the four fisheries (TWL1 = January-May Trawl, TWL2 = June-December Trawl, LGL = longline, POT = pot). The right-hand portion of the table lists the type of survey (shelf or slope) and, in the case of the shelf survey, the portion of the time series, to which each parameter value applies.

	Fishery Selectivity					Survey Selectivity	
Parameter	Era	TWL1	TWL2	LGL	POT	Type/Era	Value
peak location	FOR	69.152	72.391	70.676		Shelf/pre-'82	34.647
peak location	DOM	70.468	77.249	67.380	68.626	Shelf/post-'81	33.517
peak location	NEW	74.412	77.568	65.362	64.620	Slope	56.547
S(Lmin)	FOR	0.001	0.001	0.001		Shelf/pre-'82	0.024
S(Lmin)	DOM	0.001	0.001	0.001	0.001	Shelf/post-'81	0.017
S(Lmin)	NEW	0.001	0.001	0.001	0.001	Slope	0.002
logit(infl1)	FOR	1.310	1.291	1.327		Shelf/pre-'82	0.816
logit(infl1)	DOM	1.462	0.749	1.440	1.695	Shelf/post-'81	0.130
logit(infl1)	NEW	1.690	0.971	1.500	1.928	Slope	1.724
Slope1	FOR	0.059	0.135	0.219		Shelf/pre-'82	0.155
Slope1	DOM	0.017	0.164	0.223	0.217	Shelf/post-'81	0.080
Slope1	NEW	0.061	0.120	0.202	0.243	Slope	0.227
logit(S(Lmax))	FOR	-1.061	-0.373	-1.816		Shelf/pre-'82	2.124
logit(S(Lmax))	DOM	-0.850	1.077	-1.476	-1.059	Shelf/post-'81	1.004
logit(S(Lmax))	NEW	1.465	1.409	-0.443	-0.042	Slope	1.962
logit(infl2)	FOR	-0.558	-0.170	-0.588		Shelf/pre-'82	-0.100
logit(infl2)	DOM	0.767	0.141	0.634	0.886	Shelf/post-'81	-2.499
logit(infl2)	NEW	0.344	0.111	-0.915	-0.627	Slope	-0.154
Slope2	FOR	0.213	0.205	0.210		Shelf/pre-'82	0.200
Slope2	DOM	0.179	0.201	0.104	0.174	Shelf/post-'81	0.191
Slope2	NEW	0.201	0.201	0.180	0.184	Slope	0.200
peak width	FOR	9.660	9.953	9.453		Shelf/pre-'82	9.965
peak width	DOM	10.292	10.251	9.061	10.185	Shelf/post-'81	4.465
peak width	NEW	10.315	10.184	8.629	9.135	Slope	9.925

Table 2.22a—Schedules of Pacific cod selectivities at length in the commercial fisheries as defined by final parameter estimates. Lengths (cm) correspond to mid-points of size bins. Len. = length, FOR = 1964-1988, DOM = 1989-1999, NEW = 2000-2005.

	Jan-May Trawl Fishery			Jul-Dec Trawl Fishery			Longline Fishery			Pot Fishery	
Len.	FOR	DOM	NEW	FOR	DOM	NEW	FOR	DOM	NEW	DOM	NEW
10.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19.5	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22.5	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
25.5	0.02	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
28.5	0.03	0.02	0.01	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00
31.5	0.04	0.04	0.01	0.01	0.02	0.02	0.00	0.00	0.00	0.00	0.00
34.5	0.06	0.05	0.01	0.02	0.03	0.03	0.01	0.01	0.01	0.00	0.00
37.5	0.09	0.08	0.02	0.03	0.05	0.05	0.01	0.01	0.02	0.00	0.00
40.5	0.13	0.11	0.03	0.05	0.08	0.08	0.02	0.02	0.03	0.01	0.01
43.5	0.17	0.14	0.05	0.08	0.12	0.11	0.03	0.04	0.06	0.02	0.01
47.5	0.25	0.21	0.09	0.14	0.21	0.18	0.08	0.11	0.14	0.05	0.05
52.5	0.38	0.32	0.16	0.26	0.38	0.30	0.23	0.29	0.35	0.15	0.18
57.5	0.54	0.46	0.27	0.45	0.59	0.46	0.49	0.58	0.65	0.38	0.50
62.5	0.73	0.63	0.43	0.66	0.78	0.63	0.77	0.85	0.90	0.71	0.88
67.5	0.93	0.85	0.64	0.86	0.90	0.79	0.94	1.00	1.00	0.96	1.00
72.5	1.00	1.00	0.90	1.00	0.97	0.92	1.00	1.00	1.00	1.00	1.00
77.5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.89	1.00	0.93
82.5	0.90	1.00	1.00	1.00	1.00	1.00	0.91	0.96	0.73	0.99	0.82
87.5	0.70	0.97	0.99	0.90	1.00	1.00	0.69	0.87	0.58	0.96	0.69
92.5	0.50	0.88	0.96	0.75	0.96	0.97	0.44	0.74	0.48	0.88	0.59
97.5	0.35	0.72	0.91	0.58	0.88	0.91	0.27	0.56	0.43	0.70	0.53
102.5	0.28	0.49	0.85	0.47	0.80	0.85	0.18	0.37	0.40	0.47	0.50
107.5	0.26	0.30	0.81	0.41	0.75	0.80	0.14	0.19	0.39	0.26	0.49

Table 2.22b—Schedules of Pacific cod selectivities at length in the bottom trawl surveys as defined by final parameter estimates. Lengths (cm) correspond to lower bounds of size bins.

	Shelf Survey		
Length	Pre-1982	Post-1981	Slope
10.5	0.03	0.06	0.00
13.5	0.05	0.16	0.00
16.5	0.09	0.27	0.00
19.5	0.16	0.40	0.00
22.5	0.28	0.53	0.00
25.5	0.43	0.66	0.00
28.5	0.62	0.79	0.00
31.5	0.81	0.92	0.01
34.5	0.99	1.00	0.01
37.5	1.00	1.00	0.03
40.5	1.00	0.92	0.07
43.5	1.00	0.86	0.16
47.5	1.00	0.81	0.37
52.5	1.00	0.77	0.74
57.5	1.00	0.75	1.00
62.5	0.99	0.74	1.00
67.5	0.98	0.73	1.00
72.5	0.96	0.73	0.99
77.5	0.93	0.73	0.98
82.5	0.91	0.73	0.96
87.5	0.90	0.73	0.93
92.5	0.90	0.73	0.90
97.5	0.89	0.73	0.89
102.5	0.89	0.73	0.88
107.5	0.89	0.73	0.88

Table 2.23—Schedules of Pacific cod selectivities at age for the most recent portion of the time series as implied by final parameter estimates. Per. 1 = January-May, Per. 2 = June-August, Per. 3 = September-December. Because selectivity is defined as a function of length, not age, profiles of selectivity at age do not necessarily reach a peak value of 1.

	Trawl Fishery			Longline Fishery			Pot Fishery			Surveys	
Age	Per. 1	Per. 2	Per. 3	Per. 1	Per. 2	Per. 3	Per. 1	Per. 2	Per. 3	Shelf	Slope
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
1	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00
2	0.00	0.02	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.82	0.01
3	0.03	0.09	0.13	0.03	0.06	0.11	0.01	0.02	0.05	0.90	0.14
4	0.10	0.25	0.31	0.19	0.29	0.38	0.11	0.19	0.28	0.81	0.51
5	0.26	0.46	0.52	0.50	0.59	0.66	0.40	0.50	0.58	0.77	0.80
6	0.46	0.65	0.70	0.72	0.77	0.80	0.67	0.72	0.76	0.75	0.92
7	0.65	0.78	0.81	0.81	0.82	0.81	0.80	0.81	0.82	0.74	0.95
8	0.78	0.86	0.88	0.80	0.79	0.77	0.82	0.82	0.81	0.74	0.95
9	0.85	0.90	0.90	0.75	0.73	0.72	0.80	0.78	0.77	0.73	0.95
10	0.88	0.91	0.91	0.70	0.68	0.66	0.76	0.74	0.73	0.73	0.94
11	0.89	0.91	0.91	0.64	0.63	0.62	0.72	0.70	0.69	0.73	0.93
12	0.90	0.91	0.91	0.60	0.59	0.58	0.68	0.67	0.66	0.73	0.92
13	0.90	0.90	0.90	0.57	0.56	0.55	0.65	0.64	0.64	0.73	0.91
14	0.89	0.89	0.89	0.54	0.53	0.53	0.63	0.62	0.62	0.73	0.91
15	0.89	0.89	0.89	0.52	0.51	0.51	0.61	0.61	0.60	0.73	0.90
16	0.88	0.88	0.88	0.50	0.50	0.50	0.60	0.59	0.59	0.73	0.90
17	0.88	0.88	0.87	0.49	0.49	0.49	0.59	0.58	0.58	0.73	0.90
18	0.87	0.87	0.87	0.48	0.48	0.48	0.58	0.57	0.57	0.73	0.90
19	0.87	0.87	0.87	0.47	0.47	0.47	0.57	0.57	0.56	0.73	0.89
20	0.87	0.86	0.86	0.47	0.46	0.46	0.56	0.56	0.56	0.73	0.89

Table 2.24—Schedules of Pacific cod length (cm), proportion mature, and weight (kg) at period and age as estimated by Model 3. Pop. = population, Per. 1 = Jan-Jun, Per. 2 = Jul-Aug, Per. 3 = Sep-Dec, Beg. = beginning of period, Mid. = middle of period, SDev. = standard deviation, Mat. = proportion mature, Twl. = trawl fishery, Lgl. = longline fishery, pot = pot fishery, shelf = shelf survey, slope = slope survey.

		Length				Pop. Weight		Fishery/Survey Weight				
Per.	Age	Beg.	Mid.	S.Dev.	Mat.	Beg.	Mid.	Twl.	Lgl.	Pot	Shelf	Slope
1	0	-4.096	-0.884	1.253	0.000	0.009	0.009	0.009	0.009	0.009	0.009	0.009
1	1	10.541	13.351	3.086	0.001	0.011	0.021	0.022	0.022	0.021	0.026	0.021
1	2	23.346	25.805	4.731	0.010	0.129	0.178	0.232	0.230	0.189	0.197	0.233
1	3	34.549	36.700	6.245	0.057	0.459	0.559	0.789	0.918	1.028	0.557	0.938
1	4	44.350	46.232	7.606	0.201	1.036	1.185	1.666	1.772	2.017	1.140	1.635
1	5	52.925	54.572	8.826	0.420	1.833	2.023	2.773	2.614	2.825	1.973	2.365
1	6	60.427	61.868	9.916	0.619	2.816	3.039	3.916	3.454	3.625	2.998	3.245
1	7	66.990	68.250	10.886	0.755	3.936	4.181	5.007	4.296	4.469	4.150	4.275
1	8	72.732	73.835	11.747	0.839	5.141	5.397	6.075	5.145	5.353	5.375	5.399
1	9	77.755	78.720	12.511	0.889	6.378	6.633	7.127	6.015	6.268	6.616	6.562
1	10	82.150	82.994	13.186	0.921	7.585	7.826	8.140	6.901	7.196	7.814	7.705
1	11	85.995	86.734	13.783	0.942	8.705	8.922	9.081	7.778	8.103	8.912	8.771
1	12	89.359	90.005	14.310	0.956	9.697	9.886	9.924	8.613	8.953	9.878	9.721
1	13	92.302	92.867	14.717	0.966	10.550	10.710	10.657	9.383	9.725	10.703	10.542
1	14	94.877	95.371	15.073	0.973	11.267	11.401	11.287	10.071	10.407	11.396	11.237
2	0	2.241	4.074	1.253	n/a	0.009	0.009	0.009	0.009	0.009	0.009	0.009
2	1	16.085	17.689	3.086	n/a	0.011	0.021	0.063	0.055	0.053	0.061	0.054
2	2	28.197	29.600	4.731	n/a	0.129	0.178	0.360	0.403	0.344	0.298	0.429
2	3	38.793	40.020	6.245	n/a	0.459	0.559	1.007	1.198	1.382	0.722	1.173
2	4	48.063	49.137	7.606	n/a	1.036	1.185	1.896	2.050	2.292	1.392	1.863
2	5	56.173	57.113	8.826	n/a	1.833	2.023	2.914	2.890	3.084	2.295	2.636
2	6	63.269	64.091	9.916	n/a	2.816	3.039	3.994	3.731	3.898	3.369	3.571
2	7	69.476	70.195	10.886	n/a	3.936	4.181	5.101	4.575	4.756	4.551	4.639
2	8	74.907	75.536	11.747	n/a	5.141	5.397	6.209	5.431	5.653	5.788	5.782
2	9	79.658	80.209	12.511	n/a	6.378	6.633	7.291	6.308	6.576	7.021	6.946
2	10	83.815	84.297	13.186	n/a	7.585	7.826	8.313	7.196	7.501	8.192	8.070
2	11	87.452	87.873	13.783	n/a	8.705	8.922	9.245	8.063	8.394	9.249	9.101
2	12	90.633	91.002	14.310	n/a	9.697	9.886	10.069	8.878	9.220	10.169	10.009
2	13	93.417	93.739	14.717	n/a	10.550	10.710	10.780	9.622	9.962	10.948	10.787
2	14	95.852	96.134	15.073	n/a	11.267	11.401	11.387	10.282	10.613	11.600	11.442
3	0	5.877	8.235	1.253	n/a	0.009	0.009	0.009	0.009	0.009	0.009	0.009
3	1	19.266	21.329	3.086	n/a	0.011	0.021	0.118	0.108	0.097	0.109	0.104
3	2	30.980	32.784	4.731	n/a	0.129	0.178	0.511	0.604	0.593	0.401	0.643
3	3	41.228	42.806	6.245	n/a	0.459	0.559	1.244	1.444	1.666	0.890	1.372
3	4	50.193	51.574	7.606	n/a	1.036	1.185	2.179	2.291	2.522	1.633	2.071
3	5	58.037	59.245	8.826	n/a	1.833	2.023	3.221	3.132	3.312	2.593	2.889
3	6	64.899	65.956	9.916	n/a	2.816	3.039	4.311	3.975	4.141	3.704	3.869
3	7	70.903	71.828	10.886	n/a	3.936	4.181	5.421	4.821	5.012	4.907	4.964
3	8	76.155	76.964	11.747	n/a	5.141	5.397	6.526	5.683	5.918	6.149	6.120
3	9	80.750	81.458	12.511	n/a	6.378	6.633	7.595	6.566	6.846	7.371	7.279
3	10	84.770	85.390	13.186	n/a	7.585	7.826	8.594	7.452	7.766	8.513	8.381
3	11	88.287	88.829	13.783	n/a	8.705	8.922	9.496	8.308	8.643	9.532	9.379
3	12	91.364	91.838	14.310	n/a	9.697	9.886	10.288	9.103	9.446	10.410	10.249
3	13	94.056	94.471	14.717	n/a	10.550	10.710	10.968	9.823	10.162	11.151	10.990
3	14	96.411	96.774	15.073	n/a	11.267	11.401	11.545	10.458	10.786	11.768	11.612

Table 2.25—Time series of EBS Pacific cod age 3+ biomass and spawning biomass for the years 1977-2005 as estimated in last year's and this year's assessments, with 95% confidence intervals ("SB 95% CI") for spawning biomass as estimated in this year's assessment. Note that last year's model used 1978 as the initial year, so age 3+ and spawning biomass for 1977 are not available from that assessment. Biomass values are in 1000s of t.

	Age 3+ Biomass		Spawning Biomass		SB 95% CI (This Year)	
Year	Last Year	This Year	Last Year	This Year	Lower	Upper
1977	n/a	204	n/a	38	20	56
1978	435	249	40	52	34	70
1979	732	465	65	81	63	99
1980	1145	841	113	140	122	158
1981	1547	1135	202	249	231	267
1982	1862	1405	333	390	370	410
1983	2066	1566	465	518	495	541
1984	2174	1625	554	594	569	619
1985	2237	1715	588	615	589	641
1986	2264	1684	590	609	585	633
1987	2281	1731	592	609	589	629
1988	2224	1688	591	605	589	621
1989	2040	1541	572	577	564	590
1990	1844	1376	550	544	532	556
1991	1682	1245	497	490	477	503
1992	1548	1165	419	410	392	428
1993	1505	1133	366	369	343	395
1994	1518	1153	353	371	331	411
1995	1488	1180	341	375	318	432
1996	1371	1097	322	360	288	432
1997	1249	1004	304	347	266	428
1998	1115	904	275	311	227	395
1999	1080	911	250	292	208	376
2000	1076	905	233	285	203	367
2001	1091	916	231	288	208	368
2002	1141	979	233	299	222	376
2003	1168	1018	233	305	233	377
2004	1155	1002	239	316	250	382
2005	n/a	963	n/a	321	263	379

Table 2.26—Time series of EBS Pacific cod age 0 recruitment (1000s of fish) as estimated in last year's and this year's assessments, 1977-2004. Because last year's assessment used 1 as the initial age in the model, age 0 recruitments for last year's assessment were inferred here by multiplying last year's estimates of age 1 recruits by exp(0.37), where 0.37 is the value of the natural mortality rate used in last year's assessment. The columns labeled "L95%CI" and "U95%CI" under this year's assessment represent the lower and upper bounds of the 95% confidence interval for each cohort. Bold font indicates a value from this year's assessment in excess of the 1977-2004 average of 425,726,964 fish.

	Last Year's Assess.	This Year's Assessment		
Year	Recruits	Recruits	L95%CI	U95%CI
1977	1702536	**1296190**	**1005349**	**1670936**
1978	890357	286612	158755	**517401**
1979	1311648	**539494**	387970	**750221**
1980	309815	219689	134440	358984
1981	1200172	305763	209298	**446720**
1982	1395616	**961793**	**777325**	**1190063**
1983	819418	181580	113446	290657
1984	1350736	**837669**	**678629**	**1033994**
1985	574751	228249	159306	327033
1986	370620	158971	109790	230196
1987	322845	118590	76141	184570
1988	874432	**438700**	346860	**554872**
1989	1148054	**756024**	**616221**	**927534**
1990	655824	382243	291990	**500394**
1991	862850	413440	323329	**528671**
1992	877327	**610700**	**499303**	**746959**
1993	340218	164331	118963	226990
1994	412604	217895	165623	286658
1995	693465	423154	340535	**525828**
1996	833895	**564482**	**463699**	**687158**
1997	521184	262067	206172	333121
1998	670301	421962	340541	**522840**
1999	1088696	**627726**	**512115**	**769429**
2000	681883	**459832**	366261	**577293**
2001	516841	206703	153791	277818
2002	376411	302114	226324	403300
2003	545796	203634	138859	298625
2004	n/a	330748	204693	**534433**

Table 2.27—Time series of EBS Pacific cod catch divided by age 3+ biomass as estimated in last year's and this year's assessments, 1977-2005. Note that last year's model used 1978 as the initial year, so an estimate of the ratio for 1977 is not available from that assessment. Also, note that the last entry in each column is based on partial catches for the respective year, because the year was/is still in progress at the time of the assessment.

Year	Last Year	This Year
1977	n/a	0.16
1978	0.10	0.17
1979	0.05	0.07
1980	0.04	0.05
1981	0.04	0.05
1982	0.03	0.04
1983	0.05	0.06
1984	0.06	0.08
1985	0.06	0.08
1986	0.06	0.08
1987	0.07	0.09
1988	0.09	0.12
1989	0.09	0.12
1990	0.09	0.13
1991	0.12	0.17
1992	0.11	0.14
1993	0.09	0.12
1994	0.11	0.15
1995	0.15	0.19
1996	0.15	0.19
1997	0.19	0.23
1998	0.14	0.18
1999	0.14	0.16
2000	0.14	0.17
2001	0.13	0.16
2002	0.15	0.17
2003	0.15	0.17
2004	0.13	0.18
2005	n/a	0.15

Table 2.28—Definitions of labels and terms used in the Pacific cod projection tables.

Symbol	Definition
SPR	Equilibrium spawning per recruit, expressed as a percentage of the maximum level
L90%CI	Lower bound of the 90% confidence interval
Median	Point that divides projection outputs into two groups of equal size (50% higher, 50% lower)
Mean	Average value of the projection outputs
U90%CI	Upper bound of the 90% confidence interval
Std. Dev.	Standard deviation of the projection outputs

Table 2.29—Equilibrium reference points and projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in 2006-2018 (Scenarios 1 and 2), with random variability in future recruitment. See Table 2.28 for label definitions.

Equilibrium Reference Points

SPR	Catch	Spawning Bio.	Fishing Mort.
100%	0	863000	0
40%	198000	345000	0.32
35%	212000	302000	0.38

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	183255	183256	183256	183258	1
2007	156418	156422	156423	156430	4
2008	136316	136406	136433	136631	106
2009	131323	132860	133308	136658	1806
2010	135110	146611	149644	174854	13058
2011	135874	169418	175786	230050	30796
2012	134435	194724	195904	267056	42131
2013	135117	208105	207777	286873	47561
2014	135938	213564	214862	298004	49771
2015	137017	216203	218807	302125	50812
2016	139511	218174	220987	306100	50965
2017	140865	220220	222773	308537	51010
2018	147592	222367	224895	311810	50999

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	333728	333728	333728	333728	0
2007	312877	312879	312880	312884	2
2008	294596	294729	294769	295061	157
2009	287456	289242	289746	293602	2058
2010	288747	299052	301545	322469	11171
2011	289384	317640	323716	375181	28556
2012	289039	338026	346280	434203	46083
2013	288901	354572	364075	471180	58215
2014	291583	363762	376680	492210	65189
2015	292806	373277	384934	509669	69120
2016	295972	380390	390024	513823	71219
2017	297610	382524	393722	524196	72441
2018	302106	386621	397183	532411	73179

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	0.306	0.306	0.306	0.306	0.000
2007	0.286	0.286	0.286	0.286	0.000
2008	0.268	0.268	0.268	0.269	0.000
2009	0.261	0.263	0.264	0.267	0.002
2010	0.263	0.272	0.275	0.295	0.010
2011	0.263	0.290	0.292	0.317	0.018
2012	0.263	0.310	0.301	0.317	0.019
2013	0.263	0.317	0.305	0.317	0.019
2014	0.265	0.317	0.307	0.317	0.018
2015	0.266	0.317	0.308	0.317	0.018
2016	0.270	0.317	0.309	0.317	0.017
2017	0.271	0.317	0.310	0.317	0.016
2018	0.275	0.317	0.310	0.317	0.015

Table 2.30—Equilibrium reference points and projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that F = ½ *max* F_{ABC} in 2006-2018 (Scenario 3), with random variability in future recruitment. See Table 2.28 for label definitions.

Equilibrium Reference Points

SPR	Catch	Spawning Bio.	Fishing Mort.
100%	0	863000	0
40%	198000	345000	0.32
35%	212000	302000	0.38

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	96083	96083	96083	96084	0
2007	98103	98105	98106	98110	2
2008	96245	96300	96316	96437	64
2009	97372	97818	97950	98929	524
2010	100337	104313	105340	113745	4436
2011	101617	113925	116629	139358	12576
2012	101684	124708	128137	166231	20404
2013	104006	135000	137914	184841	25544
2014	106454	141784	145865	195386	28566
2015	108346	148574	152029	204867	30398
2016	111883	153457	156451	210194	31356
2017	114040	156412	159649	215240	31741
2018	116923	159122	161975	218763	31773

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	339631	339631	339631	339631	0
2007	349279	349281	349282	349287	3
2008	350477	350613	350653	350949	159
2009	353841	355692	356214	360209	2133
2010	361015	372050	374662	397026	11907
2011	366748	398151	405153	463041	32026
2012	369824	431272	440760	541879	55066
2013	376784	466320	475402	611591	73950
2014	385090	494470	506384	655516	87291
2015	395210	521562	532430	705385	96255
2016	407798	541953	552973	729694	101783
2017	416519	560847	568686	751747	104811
2018	429858	572217	580443	763583	106033

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	0.153	0.153	0.153	0.153	0.000
2007	0.157	0.157	0.157	0.157	0.000
2008	0.158	0.158	0.158	0.158	0.000
2009	0.159	0.159	0.159	0.159	0.000
2010	0.159	0.159	0.159	0.159	0.000
2011	0.159	0.159	0.159	0.159	0.000
2012	0.159	0.159	0.159	0.159	0.000
2013	0.159	0.159	0.159	0.159	0.000
2014	0.159	0.159	0.159	0.159	0.000
2015	0.159	0.159	0.159	0.159	0.000
2016	0.159	0.159	0.159	0.159	0.000
2017	0.159	0.159	0.159	0.159	0.000
2018	0.159	0.159	0.159	0.159	0.000

Table 2.31—Equilibrium reference points and projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that *F* = the 2001-2005 average in 2006-2018 (Scenario 4), with random variability in future recruitment. See Table 2.28 for label definitions.

Equilibrium Reference Points

SPR	Catch	Spawning Bio.	Fishing Mort.
100%	0	863000	0
40%	198000	345000	0.32
35%	212000	302000	0.38

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	174513	174513	174514	174515	1
2007	159956	159959	159960	159965	3
2008	147160	147193	147203	147274	38
2009	143363	144184	144427	146227	963
2010	145053	152234	154083	169263	8009
2011	144167	165572	170391	210361	21965
2012	141841	180339	185879	248284	33994
2013	142787	192584	197179	267306	40533
2014	143705	198311	204723	281127	43483
2015	145049	204069	209297	286555	44850
2016	147779	206931	211823	291226	45317
2017	150375	208932	213837	291805	45444
2018	153615	211386	216046	296734	45562

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	334341	334341	334341	334341	0
2007	315843	315845	315846	315851	3
2008	295573	295711	295752	296054	162
2009	284149	286009	286535	290556	2146
2010	281266	292238	294836	317064	11834
2011	279008	309820	316387	372595	31064
2012	275987	333075	341681	438039	51133
2013	277104	357064	363862	480864	65194
2014	279571	370501	380904	509210	73256
2015	281441	382986	392858	532226	77589
2016	287957	393226	400684	535296	79638
2017	291139	399876	406341	548030	80561
2018	297133	403809	411261	553760	81012

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	0.290	0.290	0.290	0.290	0.000
2007	0.290	0.290	0.290	0.290	0.000
2008	0.290	0.290	0.290	0.290	0.000
2009	0.290	0.290	0.290	0.290	0.000
2010	0.290	0.290	0.290	0.290	0.000
2011	0.290	0.290	0.290	0.290	0.000
2012	0.290	0.290	0.290	0.290	0.000
2013	0.290	0.290	0.290	0.290	0.000
2014	0.290	0.290	0.290	0.290	0.000
2015	0.290	0.290	0.290	0.290	0.000
2016	0.290	0.290	0.290	0.290	0.000
2017	0.290	0.290	0.290	0.290	0.000
2018	0.290	0.290	0.290	0.290	0.000

Table 2.32—Equilibrium reference points and projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that *F* = 0 in 2006-2018 (Scenario 5), with random variability in future recruitment. See Table 2.28 for label definitions.

Equilibrium Reference Points

SPR	Catch	Spawning Bio.	Fishing Mort.
100%	0	863000	0
40%	198000	345000	0.32
35%	212000	302000	0.38

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	0	0	0	0	0
2007	0	0	0	0	0
2008	0	0	0	0	0
2009	0	0	0	0	0
2010	0	0	0	0	0
2011	0	0	0	0	0
2012	0	0	0	0	0
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	345643	345643	345643	345643	0
2007	391750	391752	391753	391758	3
2008	429503	429641	429682	429985	162
2009	465119	466985	467512	471544	2152
2010	499801	510954	513581	536168	12026
2011	529805	562275	569537	629839	33250
2012	554222	620532	631467	739381	60313
2013	580000	682287	694502	855536	86502
2014	605080	741598	755125	948646	108822
2015	629498	792586	810148	1038040	126506
2016	657212	841036	856683	1104280	139195
2017	683255	878777	893131	1145360	147015
2018	703153	908288	918796	1173860	150378

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	0.000	0.000	0.000	0.000	0.000
2007	0.000	0.000	0.000	0.000	0.000
2008	0.000	0.000	0.000	0.000	0.000
2009	0.000	0.000	0.000	0.000	0.000
2010	0.000	0.000	0.000	0.000	0.000
2011	0.000	0.000	0.000	0.000	0.000
2012	0.000	0.000	0.000	0.000	0.000
2013	0.000	0.000	0.000	0.000	0.000
2014	0.000	0.000	0.000	0.000	0.000
2015	0.000	0.000	0.000	0.000	0.000
2016	0.000	0.000	0.000	0.000	0.000
2017	0.000	0.000	0.000	0.000	0.000
2018	0.000	0.000	0.000	0.000	0.000

Table 2.33—Equilibrium reference points and projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = F_{OFL}$ in 2006-2018 (Scenario 6), with random variability in future recruitment. See Table 2.28 for label definitions.

Equilibrium Reference Points

SPR	Catch	Spawning Bio.	Fishing Mort.
100%	0	863000	0
40%	198000	345000	0.32
35%	212000	302000	0.38

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	215684	215685	215685	215687	1
2007	171993	171997	171998	172007	5
2008	144637	144738	144768	144990	119
2009	137950	139668	140169	143915	2020
2010	142048	154880	158331	186497	14883
2011	142582	179682	188679	262423	37888
2012	140595	206015	212313	302432	51687
2013	140287	223108	224624	318568	56917
2014	140030	228628	229936	326069	58388
2015	140732	230364	231722	326966	58951
2016	141801	231054	232040	328227	58888
2017	141194	233460	233082	330343	58925
2018	146602	235958	235065	332249	59139

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	331407	331407	331407	331407	0
2007	299815	299817	299818	299822	2
2008	276781	276914	276953	277244	156
2009	268122	269899	270400	274237	2047
2010	269080	279299	281772	302519	11066
2011	269489	297184	303060	353148	27764
2012	268491	316363	323071	402202	43034
2013	268325	329367	336509	433142	52213
2014	269167	334591	344000	445905	56617
2015	269276	336797	347539	454854	58742
2016	270364	337675	348963	453230	59727
2017	270785	339352	350248	459702	60350
2018	275388	342278	352258	463671	60746

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	0.367	0.367	0.367	0.367	0.000
2007	0.330	0.330	0.330	0.330	0.000
2008	0.303	0.303	0.303	0.304	0.000
2009	0.293	0.295	0.296	0.300	0.002
2010	0.294	0.306	0.309	0.333	0.013
2011	0.295	0.327	0.332	0.383	0.026
2012	0.293	0.349	0.347	0.383	0.031
2013	0.293	0.365	0.354	0.383	0.032
2014	0.294	0.371	0.357	0.383	0.031
2015	0.294	0.373	0.358	0.383	0.031
2016	0.296	0.374	0.359	0.383	0.031
2017	0.296	0.376	0.360	0.383	0.030
2018	0.302	0.380	0.360	0.383	0.030

Table 2.34—Equilibrium reference points and projections for BSAI Pacific cod catch (t), spawning biomass (t), and fishing mortality under the assumption that $F = max\ F_{ABC}$ in each year 2006-2007 and $F = F_{OFL}$ thereafter (Scenario 7), with random variability in future recruitment. See Table 2.28 for label definitions.

Equilibrium Reference Points

SPR	Catch	Spawning Bio.	Fishing Mort.
100%	0	863000	0
40%	198000	345000	0.32
35%	212000	302000	0.38

Catch Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	183255	183256	183256	183258	1
2007	156418	156422	156423	156430	4
2008	160957	161063	161094	161327	124
2009	146553	148317	148832	152679	2074
2010	146332	159333	162818	191329	15016
2011	144389	181731	190570	263189	37707
2012	141382	207160	213181	303126	51575
2013	141426	224246	225808	319609	57015
2014	141234	230930	231980	328618	58723
2015	142445	233547	234270	330061	59401
2016	143296	234352	234533	331042	59284
2017	142402	235611	235095	332604	59177
2018	147529	237270	236469	334030	59275

Spawning Biomass Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	333728	333728	333728	333728	0
2007	312877	312879	312880	312884	2
2008	292803	292935	292975	293265	156
2009	277273	279047	279548	283377	2044
2010	273939	284129	286606	307310	11049
2011	271815	299433	305334	355451	27741
2012	269559	317532	324244	403348	43116
2013	269282	330316	337742	434524	52510
2014	270196	336082	345891	449682	57246
2015	270480	338941	349990	458604	59653
2016	271960	339696	351501	457275	60691
2017	271933	341198	352441	463971	61166
2018	276261	343625	353927	466067	61350

Fishing Mortality Projections

Year	L90%CI	Median	Mean	U90%CI	Std. Dev.
2006	0.306	0.306	0.306	0.306	0.000
2007	0.286	0.286	0.286	0.286	0.000
2008	0.322	0.322	0.322	0.322	0.000
2009	0.304	0.306	0.306	0.311	0.002
2010	0.300	0.312	0.315	0.339	0.013
2011	0.297	0.330	0.334	0.383	0.026
2012	0.295	0.351	0.348	0.383	0.030
2013	0.294	0.366	0.355	0.383	0.031
2014	0.295	0.372	0.358	0.383	0.031
2015	0.296	0.376	0.359	0.383	0.031
2016	0.298	0.377	0.360	0.383	0.030
2017	0.297	0.378	0.361	0.383	0.030
2018	0.303	0.381	0.361	0.383	0.029

Table 2.35a—Bycatch of nontarget and "other" species taken in the EBS Pacific cod trawl fishery, 1997-2002. The first part of the table ("Bycatch in...") shows the amount (t) of each species group taken as bycatch in the EBS Pacific cod trawl fishery, broken down by year. The second part of the table ("Proportion of...") shows the same quantity expressed relative to the total EBS catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the EBS during that year.

	Bycatch in EBS Pacific cod trawl fishery						Proportion of total EBS catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
sculpin	1508	1365	893	1280	749	925	0.22	0.26	0.20	0.23	0.12	0.12
skates	678	676	946	981	583	1303	0.04	0.04	0.07	0.06	0.03	0.05
shark	0	0	0	9	2	3	0.00	0.00	0.00	0.15	0.09	0.08
salmonshk	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
dogfish	0	0	0	0	0	1	0.00	0.00	0.00	0.00	0.04	0.08
sleepershk	8	33	4	0	12	10	0.03	0.10	0.01	0.00	0.02	0.01
octopus	29	19	17	68	17	30	0.14	0.13	0.13	0.19	0.09	0.08
squid	7	1	0	2	4	1	0.00	0.00	0.00	0.00	0.00	0.00
smelts	1	0	1	0	0	0	0.03	0.00	0.03	0.00	0.00	0.00
gunnel	0	0	0	0	0	0		0.00	0.00	0.00	0.71	0.00
sticheidae	0	0	0	0	0	0	0.00	0.03	0.00	0.00	0.01	0.00
sandfish	0	0	3	0	0	1	0.27	0.08	0.91	0.02	0.05	0.36
lanternfish	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
sandlance	0	0	0	0	0	0	0.00		0.00	0.00	0.90	0.01
grenadier	1	6	0	3	0	0	0.00	0.00	0.00	0.00	0.00	0.00
otherfish	231	232	195	302	220	157	0.16	0.21	0.20	0.24	0.18	0.14
crabs	10	6	5	8	3	6	0.03	0.03	0.05	0.06	0.02	0.04
starfish	133	63	83	109	57	98	0.02	0.02	0.03	0.03	0.01	0.02
jellyfish	948	213	416	413	112	93	0.11	0.03	0.06	0.04	0.03	0.05
invertunid	1	9	3	11	1	51	0.00	0.02	0.02	0.01	0.00	0.05
seapen/whip	0	0	0	0	0	0	0.10	0.09	0.01	0.06	0.00	0.00
sponge	73	34	39	28	9	13	0.23	0.09	0.22	0.30	0.05	0.08
anemone	14	5	18	10	6	9	0.08	0.05	0.11	0.03	0.03	0.03
tunicate	6	10	0	67	5	1	0.00	0.01	0.00	0.06	0.00	0.00
benthinv	25	18	11	23	6	12	0.04	0.03	0.05	0.06	0.01	0.03
snails	0	0	0	0	0	0					0.00	0.00
echinoderm	13	4	13	13	20	14	0.31	0.20	0.54	0.33	0.50	0.46
coral	0	0	0	4	0	0	0.02	0.01	0.04	0.37	0.00	0.00
shrimp	0	0	0	0	0	0	0.07	0.03	0.01	0.00	0.01	0.00
birds	0	0	0	0	0	0	0.00	0.01	0.00	0.00	0.00	0.00

Table 2.35b—Bycatch of nontarget and “other” species taken in the EBS Pacific cod trawl fishery, 2003-2005. The first part of the table (“Bycatch”) shows the amount (t) of each species group taken as bycatch in the EBS Pacific cod trawl fishery, broken down by year. The second part of the table (“Proportion of total”) shows the same quantity expressed relative to the total EBS catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the EBS during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

	Catch (t)			Proportion of total		
Species group	2003	2004	2005	2003	2004	2005
Benthic urochordata	14	4	9	0.01	0.00	0.01
Birds	0	0	0	0.00	0.01	0.00
Bivalves	1	10	0	0.05	0.52	0.03
Brittle star unidentified	1	1	0	0.02	0.03	0.00
Capelin		0			0.02	
Corals Bryozoans	1	1	0	0.28	0.25	0.06
Deep sea smelts (bathylagidae)						
Eelpouts	62	27	1	0.27	0.30	0.02
Eulachon		0	0		0.00	0.00
Giant Grenadier						
Greenlings	4	2	1	0.43	0.40	0.23
Grenadier	14	9	0	0.01	0.00	0.00
Gunnels						
Hermit crab unidentified	5	3	1	0.04	0.05	0.01
Invertebrate unidentified	5	4	0	0.01	0.01	0.00
Lanternfishes (myctophidae)		0			0.07	
Large Sculpins	547	1422	897	0.39	0.32	0.22
Misc crabs	7	3	2	0.13	0.09	0.07
Misc crustaceans	0	0	0	0.24	0.20	0.07
Misc deep fish						
Misc fish	174	152	149	0.35	0.30	0.31
Misc inverts (worms etc)	0	0	0	0.07	0.02	0.00
Octopus	14	44	12	0.10	0.12	0.05
Other osmerids	0	0		0.01	0.09	
Other Sculpins	854	95	58	0.22	0.18	0.12
Pacific Sand lance	0	0	0	0.45	0.40	0.59
Pandalid shrimp	0	0	0	0.15	0.18	0.01
Polychaete unidentified		0	0		0.01	0.08
Scypho jellies	727	699	391	0.11	0.10	0.06
Sea anemone unidentified	14	16	12	0.10	0.09	0.12
Sea pens whips	0	1	0	0.01	0.05	0.01
Sea star	118	91	81	0.03	0.03	0.03
Shark	10	29	11	0.03	0.08	0.05
Skate	1010	1355	570	0.06	0.07	0.03
Snails	14	13	3	0.07	0.05	0.02
Sponge unidentified	3	7	3	0.01	0.08	0.04
Squid	5	4	1	0.00	0.00	0.00
Stichaeidae	0	0	0	0.12	0.07	0.14
Surf smelt						
Urchins dollars cucumbers	11	10	12	0.36	0.43	0.48

Table 2.36a—Bycatch of nontarget and "other" species taken in the EBS Pacific cod longline fishery, 1997-2002. The first part of the table ("Bycatch in...") shows the amount (t) of each species group taken as bycatch in the EBS Pacific cod longline fishery, broken down by year. The second part of the table ("Proportion of...") shows the same quantity expressed relative to the total EBS catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the EBS during that year.

	Bycatch in EBS Pacific cod longline fishery						Proportion of total EBS catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
sculpin	706	931	821	801	1142	1383	0.11	0.18	0.18	0.14	0.19	0.18
skates	12961	12808	9178	11578	11932	17507	0.77	0.70	0.69	0.68	0.66	0.66
shark	27	48	18	47	17	22	0.50	0.40	0.11	0.78	0.70	0.48
salmonshk	0	1	1	0	1	10	0.00	0.05	0.04	0.01	0.05	0.22
dogfish	4	5	5	8	11	8	1.00	0.90	0.99	0.98	0.83	0.92
sleepershk	67	114	99	114	240	250	0.24	0.34	0.35	0.33	0.37	0.30
octopus	15	15	13	29	15	76	0.07	0.10	0.10	0.08	0.08	0.19
squid	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
smelts	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
gunnel	0	0	0	0	0	0		0.60	0.00	0.80	0.00	0.00
sticheidae	0	0	0	0	0	0	0.01	0.00	0.00	0.00	0.00	0.56
sandfish	0	0	0	0	0	0	0.00	0.00	0.01	0.00	0.00	0.00
lanternfish	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
sandlance	0	0	0	0	0	0	0.00		0.00	0.00	0.00	0.00
grenadier	437	604	356	364	162	336	0.15	0.12	0.08	0.09	0.07	0.06
otherfish	43	27	38	38	71	122	0.03	0.03	0.04	0.03	0.06	0.11
crabs	1	0	0	1	1	3	0.00	0.00	0.00	0.00	0.01	0.01
starfish	136	141	250	132	319	384	0.02	0.04	0.08	0.04	0.08	0.08
jellyfish	5	7	24	2	2	5	0.00	0.00	0.00	0.00	0.00	0.00
invertunid	10	12	1	6	10	11	0.01	0.02	0.01	0.01	0.01	0.01
seapen/whip	2	2	4	3	6	41	0.83	0.79	0.87	0.63	0.79	0.95
sponge	1	1	2	1	0	5	0.00	0.00	0.01	0.01	0.00	0.03
anemone	76	58	123	200	115	195	0.42	0.51	0.73	0.58	0.55	0.59
tunicate	1	1	0	2	0	1	0.00	0.00	0.00	0.00	0.00	0.00
benthinv	7	5	10	11	12	12	0.01	0.01	0.04	0.03	0.02	0.03
snails	0	0	0	0	0	0					1.00	0.00
echinoderm	1	0	3	0	0	0	0.02	0.00	0.11	0.00	0.00	0.01
coral	1	0	0	3	1	2	0.07	0.02	0.04	0.30	0.01	0.03
shrimp	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
birds	26	33	17	24	13	13	0.98	0.86	0.81	0.97	0.88	0.96

Table 2.36b—Bycatch of nontarget and "other" species taken in the EBS Pacific cod hook-and-line (including jigs) fishery, 2003-2005. The first part of the table ("Bycatch") shows the amount (t) of each species group taken as bycatch in the EBS Pacific cod hook-and-line fishery, broken down by year. The second part of the table ("Proportion of total") shows the same quantity expressed relative to the total EBS catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the EBS during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

	Byatch (t)			Proportion of total		
Species group	2003	2004	2005	2003	2004	2005
Benthic urochordata	0	0	0	0.00	0.00	0.00
Birds	6	6	2	0.93	0.93	0.44
Bivalves	4	6	5	0.36	0.33	0.68
Brittle star unidentified	0	0	0	0.01	0.00	0.01
Capelin						
Corals Bryozoans	1	1	1	0.23	0.23	0.30
Deep sea smelts (bathylagidae)						
Eelpouts	4	8	16	0.02	0.09	0.25
Eulachon						
Giant Grenadier	1	16	91	0.01	0.08	0.08
Greenlings	3	1	1	0.28	0.23	0.20
Grenadier	221	202	158	0.08	0.10	0.12
Gunnels		0	0		1.00	1.00
Hermit crab unidentified	1	0	0	0.01	0.00	0.00
Invertebrate unidentified	14	2	3	0.02	0.00	0.01
Lanternfishes (myctophidae)						
Large Sculpins	194	1087	865	0.14	0.24	0.21
Misc crabs	1	1	9	0.01	0.02	0.24
Misc crustaceans	0	0	0	0.02	0.00	0.43
Misc deep fish						
Misc fish	44	58	26	0.09	0.12	0.05
Misc inverts (worms etc)		0	0		0.00	0.01
Octopus	41	37	20	0.30	0.10	0.08
Other osmerids			0			0.00
Other Sculpins	993	234	163	0.25	0.44	0.33
Pacific Sand lance						
Pandalid shrimp						
Polychaete unidentified	0	0	0	0.13	0.01	0.64
Scypho jellies	16	4	1	0.00	0.00	0.00
Sea anemone unidentified	79	94	69	0.58	0.53	0.69
Sea pens whips	6	10	19	0.86	0.84	0.88
Sea star	288	288	202	0.07	0.10	0.08
Shark	140	146	128	0.50	0.42	0.55
Skate	13519	13863	13219	0.74	0.75	0.78
Snails	5	6	6	0.03	0.02	0.05
Sponge unidentified	3	1	2	0.01	0.01	0.02
Squid	0	0	0	0.00	0.00	0.00
Stichaeidae	0			0.05		
Surf smelt						
Urchins dollars cucumbers	0	0	0	0.00	0.00	0.00

Table 2.37a—Bycatch of nontarget and “other” species taken in the EBS Pacific cod pot fishery, 1997-2002. The first part of the table (“Bycatch in...”) shows the amount (t) of each species group taken as bycatch in the EBS Pacific cod pot fishery, broken down by year. The second part of the table (“Proportion of...”) shows the same quantity expressed relative to the total EBS catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the EBS during that year.

	Bycatch in EBS Pacific cod pot fishery						Proportion of total EBS catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
sculpin	351	267	438	494	315	384	0.05	0.05	0.10	0.09	0.05	0.05
skates	1	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
shark	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
salmonshk	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
dogfish	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
sleepershk	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
octopus	79	95	80	199	140	254	0.38	0.65	0.64	0.56	0.75	0.65
squid	0	0	0	0	1	0	0.00	0.00	0.00	0.00	0.00	0.00
smelts	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
gunnel	0	0	0	0	0	0		0.00	0.00	0.00	0.00	0.00
sticheidae	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
sandfish	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
lanternfish	0	0	0	0	0	0	0.02	0.00	0.00	0.00	0.00	0.00
sandlance	0	0	0	0	0	0	0.00		0.00	0.00	0.00	0.00
grenadier	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
otherfish	27	44	32	12	48	23	0.02	0.04	0.03	0.01	0.04	0.02
crabs	1	1	4	2	1	2	0.00	0.00	0.04	0.01	0.01	0.01
starfish	64	14	15	35	31	11	0.01	0.00	0.01	0.01	0.01	0.00
jellyfish	11	1	16	0	6	2	0.00	0.00	0.00	0.00	0.00	0.00
invertunid	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
seapen/whip	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
sponge	0	0	0	0	0	1	0.00	0.00	0.00	0.00	0.00	0.00
anemone	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
tunicate	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
benthinv	8	3	4	11	4	9	0.01	0.01	0.02	0.03	0.01	0.02
snails	0	0	0	0	0	0					0.00	0.00
echinoderm	1	0	0	2	1	0	0.02	0.02	0.02	0.04	0.02	0.01
coral	0	0	0	0	0	0	0.02	0.00	0.00	0.00	0.00	0.00
shrimp	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
birds	0	0	0	0	0	0	0.00	0.00	0.01	0.00	0.00	0.00

Table 2.37b—Bycatch of nontarget and "other" species taken in the EBS Pacific cod pot fishery, 2003-2005. The first part of the table ("Bycatch") shows the amount (t) of each species group taken as bycatch in the EBS Pacific cod pot fishery, broken down by year. The second part of the table ("Proportion of total") shows the same quantity expressed relative to the total EBS catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the EBS during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

	Byatch (t)			Proportion of total		
Species group	2003	2004	2005	2003	2004	2005
Benthic urochordata	0	0	0	0.00	0.00	0.00
Birds	0	0	0	0.01	0.00	0.01
Bivalves	0	0	0	0.01	0.02	0.01
Brittle star unidentified	0	0	0	0.00	0.00	0.00
Capelin						
Corals Bryozoans	0		0	0.01		0.01
Deep sea smelts (bathylagidae)						
Eelpouts	0			0.00		
Eulachon						
Giant Grenadier						
Greenlings	1	0	0	0.06	0.07	0.14
Grenadier						
Gunnels						
Hermit crab unidentified	0	0	0	0.00	0.00	0.00
Invertebrate unidentified	0	0	0	0.00	0.00	0.00
Lanternfishes (myctophidae)						
Large Sculpins	122	191	109	0.09	0.04	0.03
Misc crabs	0	1	1	0.01	0.02	0.04
Misc crustaceans	0	0		0.00	0.01	
Misc deep fish						
Misc fish	30	13	14	0.06	0.03	0.03
Misc inverts (worms etc)						
Octopus	49	57	187	0.35	0.15	0.76
Other osmerids						
Other Sculpins	133	13	2	0.03	0.03	0.00
Pacific Sand lance						
Pandalid shrimp						
Polychaete unidentified						
Scypho jellies	2	1	3	0.00	0.00	0.00
Sea anemone unidentified	0	0	0	0.00	0.00	0.00
Sea pens whips	0			0.00		
Sea star	41	30	27	0.01	0.01	0.01
Shark						
Skate	0	0	0	0.00	0.00	0.00
Snails	7	1	2	0.04	0.00	0.02
Sponge unidentified	1	1	0	0.00	0.01	0.00
Squid			1			0.00
Stichaeidae						
Surf smelt						
Urchins dollars cucumbers	1	1	0	0.04	0.06	0.01

Table 2.38a—Bycatch of nontarget and “other” species taken in the AI Pacific cod trawl fishery, 1997-2002. The first part of the table (“Bycatch in...”) shows the amount (t) of each species group taken as bycatch in the AI Pacific cod trawl fishery, broken down by year. The second part of the table (“Proportion of...”) shows the same quantity expressed relative to the total AI catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the AI during that year.

	Bycatch in AI Pacific cod trawl fishery						Proportion of total AI catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
sculpin	107	146	131	257	102	131	0.14	0.14	0.14	0.18	0.06	0.12
skates	37	95	38	72	49	97	0.04	0.08	0.05	0.04	0.02	0.14
shark	0	0	0	0	0	0	0.00	0.00	0.00	0.03	0.00	0.00
salmonshk	0	0	0	4	0	0	0.00	0.00	0.00	1.00	0.00	
dogfish	0	0	0	0	0	0	0.04	0.00	0.00	0.00	0.00	0.00
sleepershk	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.01	0.01
octopus	2	2	9	2	1	9	0.06	0.05	0.04	0.03	0.03	0.38
squid	1	0	0	1	2	4	0.01	0.01	0.01	0.07	0.30	0.25
smelts	0	0	0	0	0	0	0.00	0.95	0.00	1.00	1.00	0.00
gunnel	0	0	0	0	0	0			1.00		1.00	
sticheidae	0	0	0	0	0	0	0.00			0.00		
sandfish	0	0	0	0	0	0	0.00			0.00		
lanternfish	0	0	0	0	0	0	0.00	0.00				
sandlance	0	0	0	0	0	0					0.00	0.00
grenadier	0	0	0	0	0	9	0.00	0.00	0.00	0.00	0.00	0.00
otherfish	6	38	29	25	26	15	0.04	0.14	0.09	0.12	0.11	0.07
crabs	1	1	0	0	1	2	0.13	0.44	0.27	0.22	0.42	0.88
starfish	2	3	5	5	5	5	0.12	0.15	0.29	0.20	0.17	0.46
jellyfish	0	0	0	0	0	0	0.01	0.17	0.00	0.99	0.01	0.44
invertunid	0	2	3	6	2	0	0.00	0.03	0.34	0.40	0.36	0.02
seapen/whip	0	0	0	0	0	0	0.85	0.23	0.54	0.33	0.08	0.16
sponge	4	52	15	15	13	28	0.02	0.47	0.10	0.21	0.18	0.16
anemone	0	0	1	0	0	0	0.09	0.08	0.41	0.17	0.05	0.17
tunicate	0	0	0	0	1	0	0.63	0.75	0.08	0.58	0.40	0.07
benthinv	4	3	1	2	3	6	0.90	0.68	0.16	0.73	0.76	0.92
snails	0	0	0	0	0	0						
echinoderm	0	1	1	1	1	2	0.16	0.26	0.23	0.35	0.44	0.75
coral	2	8	2	8	3	11	0.07	0.48	0.03	0.24	0.15	0.52
shrimp	0	0	0	0	0	0	0.01	0.05	0.00	0.11	0.19	0.10
birds	0	1	0	0	0	0	0.02	0.11	0.02	0.04	0.01	0.16

Table 2.38b—Bycatch of nontarget and "other" species taken in the AI Pacific cod trawl fishery, 2003-2005. The first part of the table ("Bycatch") shows the amount (t) of each species group taken as bycatch in the AI Pacific cod trawl fishery, broken down by year. The second part of the table ("Proportion of total") shows the same quantity expressed relative to the total AI catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the AI during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

	Catch (t)			Proportion of total		
Species group	2003	2004	2005	2003	2004	2005
Benthic urochordata	0	0	0	0.05	0.16	0.37
Birds	0	0	0	0.21	0.01	0.38
Bivalves	15	1	0	0.99	0.92	0.81
Brittle star unidentified		0	0		0.05	0.01
Capelin						
Corals Bryozoans	24	11	12	0.40	0.35	0.24
Deep sea smelts (bathylagidae)						
Eelpouts	0	1	0	0.08	0.51	0.00
Eulachon			0			0.68
Giant Grenadier						
Greenlings	1	0	0	0.66	0.05	0.01
Grenadier		4	0		0.01	0.00
Gunnels						
Hermit crab unidentified	0	0	0	0.80	0.98	0.09
Invertebrate unidentified	0	0	0	0.09	0.00	0.02
Lanternfishes (myctophidae)						
Large Sculpins	78	159	88	0.37	0.23	0.18
Misc crabs	1	1	0	0.73	0.59	0.52
Misc crustaceans	0	0	0	0.99	0.29	0.98
Misc deep fish						
Misc fish	28	15	19	0.23	0.10	0.12
Misc inverts (worms etc)		0	0		0.29	1.00
Octopus	6	5	3	0.36	0.28	0.40
Other osmerids						
Other Sculpins	122	1	3	0.31	0.01	0.04
Pacific Sand lance	0		0	1.00		1.00
Pandalid shrimp	0	0	0	0.06	0.01	0.03
Polychaete unidentified		0	0		0.13	0.97
Scypho jellies	0	0	1	0.17	0.49	0.44
Sea anemone unidentified	0	0	0	0.61	0.31	0.32
Sea pens whips	0	0	0	0.34	0.91	0.42
Sea star	5	3	2	0.49	0.27	0.17
Shark	0	2	2	0.01	0.43	0.10
Skate	72	76	65	0.13	0.09	0.11
Snails	1	1	0	0.52	0.50	0.21
Sponge unidentified	24	18	22	0.30	0.13	0.28
Squid	3	2	1	0.10	0.11	0.07
Stichaeidae			0			0.00
Surf smelt						
Urchins dollars cucumbers	1	1	0	0.40	0.43	0.15

Table 2.39a—Bycatch of nontarget and "other" species taken in the AI Pacific cod longline fishery, 1997-2002. The first part of the table ("Bycatch in...") shows the amount (t) of each species group taken as bycatch in the AI Pacific cod longline fishery, broken down by year. The second part of the table ("Proportion of...") shows the same quantity expressed relative to the total AI catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the AI during that year.

	Bycatch in AI Pacific cod longline fishery						Proportion of total AI catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
sculpin	334	597	356	662	1004	214	0.43	0.55	0.37	0.47	0.63	0.19
skates	338	727	473	1397	2184	246	0.39	0.64	0.59	0.77	0.87	0.35
shark	0	1	0	0	0	0	0.78	0.04	0.05	0.03	0.00	0.00
salmonshk	0	0	0	0	0	0	0.00	0.02	0.00	0.00	0.00	
dogfish	0	0	0	0	1	0	0.96	0.55	0.84	0.85	0.31	0.54
sleepershk	0	0	1	0	1	2	0.00	0.00	0.02	0.00	0.03	0.49
octopus	10	21	9	13	21	8	0.27	0.47	0.05	0.20	0.51	0.32
squid	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
smelts	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
gunnel	0	0	0	0	0	0			0.00		0.00	
sticheidae	0	0	0	0	0	0	0.00			0.00		
sandfish	0	0	0	0	0	0	0.00			0.00		
lanternfish	0	0	0	0	0	0	0.00	0.00				
sandlance	0	0	0	0	0	0					0.00	0.00
grenadier	397	83	215	151	6	88	0.14	0.05	0.07	0.05	0.00	0.03
otherfish	2	5	2	6	10	3	0.02	0.02	0.01	0.03	0.04	0.01
crabs	0	0	0	0	0	0	0.00	0.01	0.01	0.01	0.04	0.00
starfish	3	7	4	13	16	3	0.22	0.41	0.28	0.51	0.59	0.25
jellyfish	0	0	0	0	0	0	0.00	0.00	0.00	0.01	0.00	0.00
invertunid	0	1	0	1	0	0	0.00	0.01	0.02	0.06	0.08	0.02
seapen/whip	0	0	0	0	0	0	0.00	0.21	0.44	0.54	0.92	0.56
sponge	0	4	3	11	4	1	0.00	0.04	0.02	0.15	0.06	0.00
anemone	0	0	1	1	0	1	0.34	0.57	0.32	0.59	0.47	0.69
tunicate	0	0	0	0	0	0	0.01	0.00	0.00	0.24	0.00	0.00
benthinv	0	0	0	0	0	0	0.02	0.00	0.02	0.06	0.04	0.03
snails	0	0	0	0	0	0						
echinoderm	0	0	0	0	0	0	0.10	0.04	0.00	0.09	0.04	0.02
coral	0	1	2	6	3	1	0.02	0.03	0.04	0.17	0.16	0.03
shrimp	0	0	0	0	0	0	0.09	0.00	0.00	0.01	0.00	0.00
birds	2	2	2	2	1	0	0.75	0.45	0.55	0.66	0.48	0.16

Table 2.39b—Bycatch of nontarget and “other” species taken in the AI Pacific cod hook-and-line (including jigs) fishery, 2003-2005. The first part of the table (“Bycatch”) shows the amount (t) of each species group taken as bycatch in the AI Pacific cod hook-and-line fishery, broken down by year. The second part of the table (“Proportion of total”) shows the same quantity expressed relative to the total AI catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the AI during that year. Note that the list of nontarget species groups used for 2003-2005 differs from that used for 1997-2002.

	Catch (t)			Proportion of total		
Species group	2003	2004	2005	2003	2004	2005
Benthic urochordata	0	0	0	0.09	0.00	0.01
Birds	0	0	0	0.03	0.21	0.29
Bivalves	0	0	0	0.00	0.02	0.18
Brittle star unidentified	0	0	0	0.00	0.00	0.00
Capelin						
Corals Bryozoans	1	1	0	0.01	0.05	0.01
Deep sea smelts (bathylagidae)						
Eelpouts	0	0	0	0.01	0.00	0.00
Eulachon						
Giant Grenadier	0	0	0	0.30	0.00	0.00
Greenlings	0	0	0	0.08	0.16	0.02
Grenadier	46	8	0	0.01	0.01	0.00
Gunnels			0			0.00
Hermit crab unidentified	0	0	0	0.01	0.00	0.00
Invertebrate unidentified	0	1	0	0.00	0.12	0.03
Lanternfishes (myctophidae)						
Large Sculpins	28	133	91	0.14	0.19	0.18
Misc crabs	0	0	0	0.00	0.01	0.01
Misc crustaceans	0	0	0	0.00	0.00	0.00
Misc deep fish						
Misc fish	1	3	1	0.01	0.02	0.00
Misc inverts (worms etc)		0	0		0.00	0.00
Octopus	8	8	4	0.54	0.49	0.55
Other osmerids			0			0.00
Other Sculpins	31	63	1	0.08	0.41	0.01
Pacific Sand lance						
Pandalid shrimp						
Polychaete unidentified	0	0	0	1.00	0.00	0.03
Scypho jellies	0	0	0	0.01	0.00	0.00
Sea anemone unidentified	0	0	0	0.24	0.23	0.58
Sea pens whips	0	0	0	0.46	0.09	0.15
Sea star	1	6	3	0.10	0.47	0.25
Shark	0	0	0	0.01	0.08	0.02
Skate	105	402	245	0.20	0.48	0.43
Snails	0	0	0	0.01	0.03	0.05
Sponge unidentified	2	5	2	0.02	0.04	0.03
Squid		0			0.00	
Stichaeidae	0			0.00		
Surf smelt						
Urchins dollars cucumbers	0	0	0	0.02	0.11	0.01

Table 2.40—Bycatch of nontarget and “other” species taken in the AI Pacific cod pot fishery, 1997-2002. The first part of the table (“Bycatch in...”) shows the amount (t) of each species group taken as bycatch in the AI Pacific cod pot fishery, broken down by year. The second part of the table (“Proportion of...”) shows the same quantity expressed relative to the total AI catch (taken in all target categories with all gears) of that species group in that year. An empty cell in the second part of the table indicates that no catch of that group was observed in the AI during that year.

	Bycatch in AI Pacific cod pot fishery						Proportion of total AI catch					
Species group	1997	1998	1999	2000	2001	2002	1997	1998	1999	2000	2001	2002
sculpin	7	12	221	211	42	0	0.01	0.01	0.23	0.15	0.03	0.00
skates	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
shark	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
salmonshk	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	
dogfish	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
sleepershk	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
octopus	24	18	182	47	17	0	0.62	0.40	0.90	0.75	0.41	0.00
squid	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
smelts	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
gunnel	0	0	0	0	0	0			0.00		0.00	
sticheidae	0	0	0	0	0	0	0.00			0.00		
sandfish	0	0	0	0	0	0	0.00			0.00		
lanternfish	0	0	0	0	0	0	0.00	0.00				
sandlance	0	0	0	0	0	0					0.00	0.00
grenadier	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
otherfish	0	0	7	1	4	0	0.00	0.00	0.02	0.01	0.02	0.00
crabs	0	0	1	1	0	0	0.00	0.06	0.51	0.61	0.31	0.00
starfish	0	0	1	1	0	0	0.00	0.00	0.05	0.05	0.00	0.00
jellyfish	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
invertunid	0	0	0	0	0	0	0.00	0.00	0.01	0.00	0.00	0.00
seapen/whip	0	0	0	0	0	0	0.00	0.00	0.00	0.07	0.00	0.00
sponge	0	0	0	4	0	0	0.00	0.00	0.00	0.06	0.00	0.00
anemone	0	0	0	0	0	0	0.00	0.01	0.00	0.00	0.00	0.00
tunicate	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
benthinv	0	0	1	0	0	0	0.00	0.01	0.09	0.12	0.00	0.00
snails	0	0	0	0	0	0						
echinoderm	0	0	1	1	0	0	0.01	0.00	0.20	0.18	0.00	0.00
coral	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
shrimp	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
birds	0	0	0	0	0	0	0.00	0.00	0.02	0.00	0.00	0.00

Table 2.41—Summary of major results for the stock assessment of Pacific cod in the BSAI region.

Tier	3b
Reference mortality rates	
M	0.30
$F_{40\%}$	0.32
$F_{35\%}$	0.38
Equilibrium spawning biomass	
$B_{35\%}$	302,000 t
$B_{40\%}$	345,000 t
$B_{100\%}$	863,000 t
Projected biomass for 2006	
Spawning (at max FABC)	334,000 t
Age 3+	1,050,000 t
ABC for 2006	
F_{ABC} (maximum permissible)	0.31
F_{ABC} (recommended)	0.31
ABC (maximum permissible)	183,000 t
ABC (recommended)	183,000 t
Overfishing level for 2006	
Fishing Mortality	0.37
Catch	216,000 t

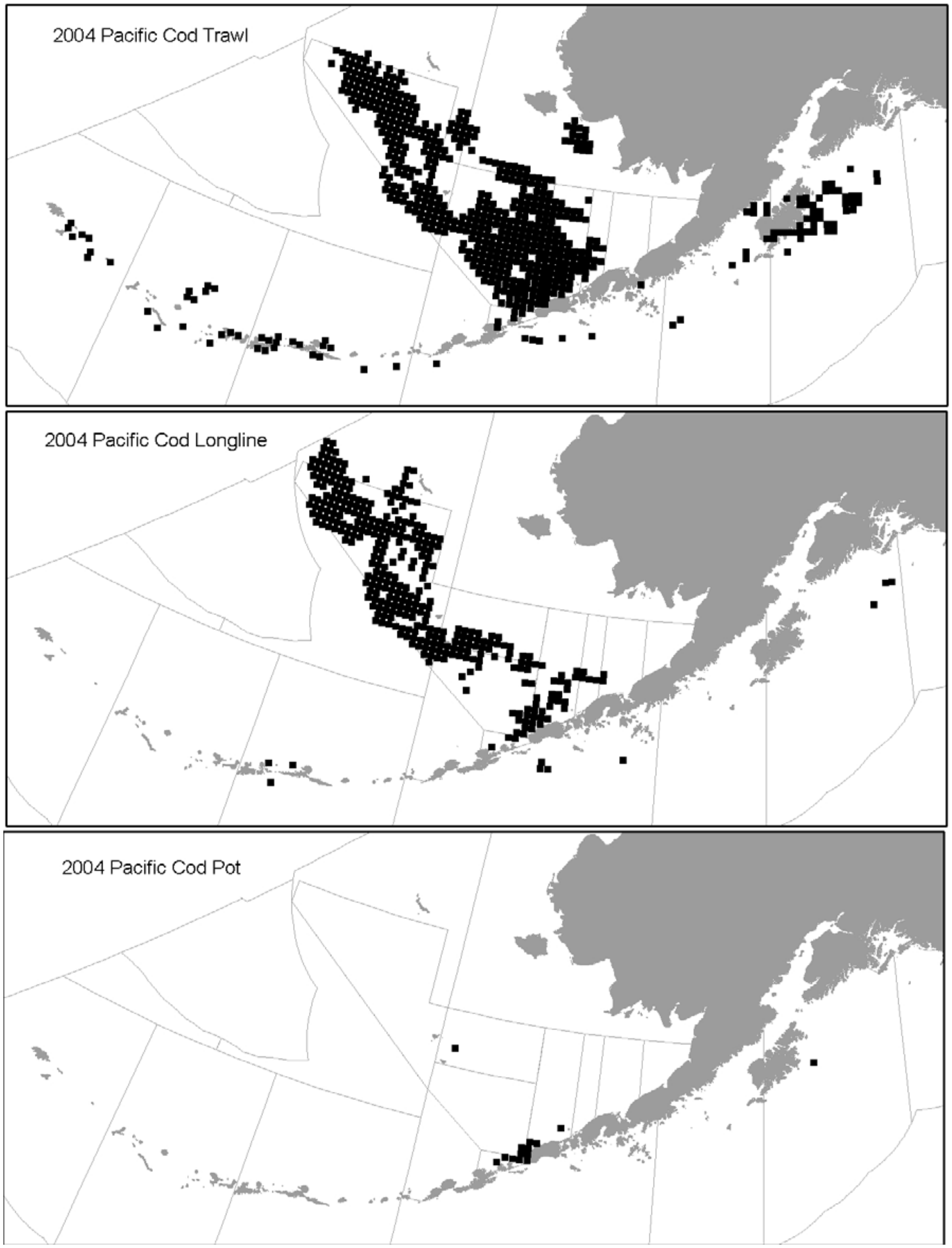

Figure 2.1a—Maps showing each 400 square kilometer cell with at least 3 observed hauls/sets containing Pacific cod in 2004, by gear type, overlaid against NMFS 3-digit statistical areas.

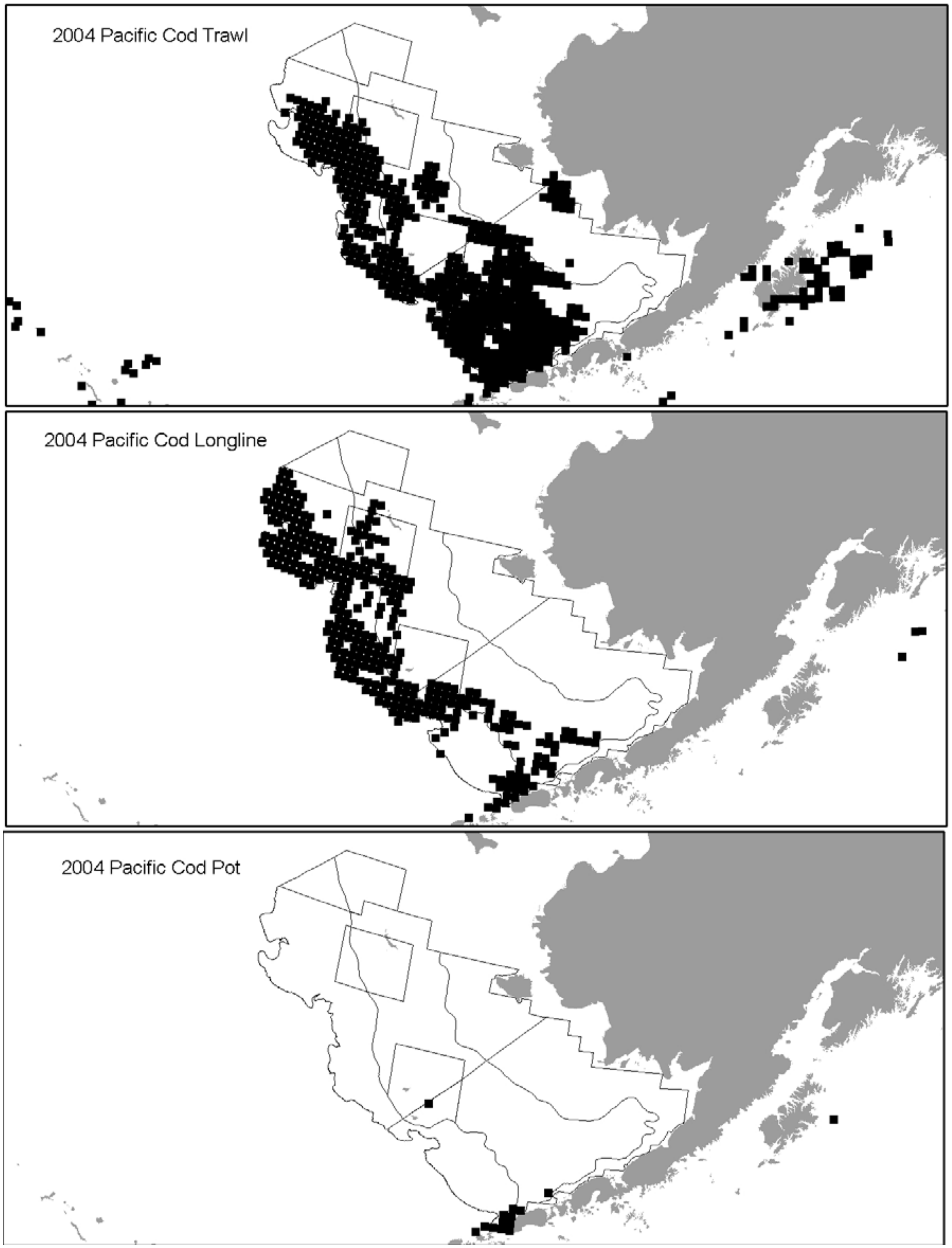

Figure 2.1b—Maps showing each 400 square kilometer cell with at least 3 observed hauls/sets containing Pacific cod in 2004, by gear type, overlaid against strata used in the EBS shelf survey.

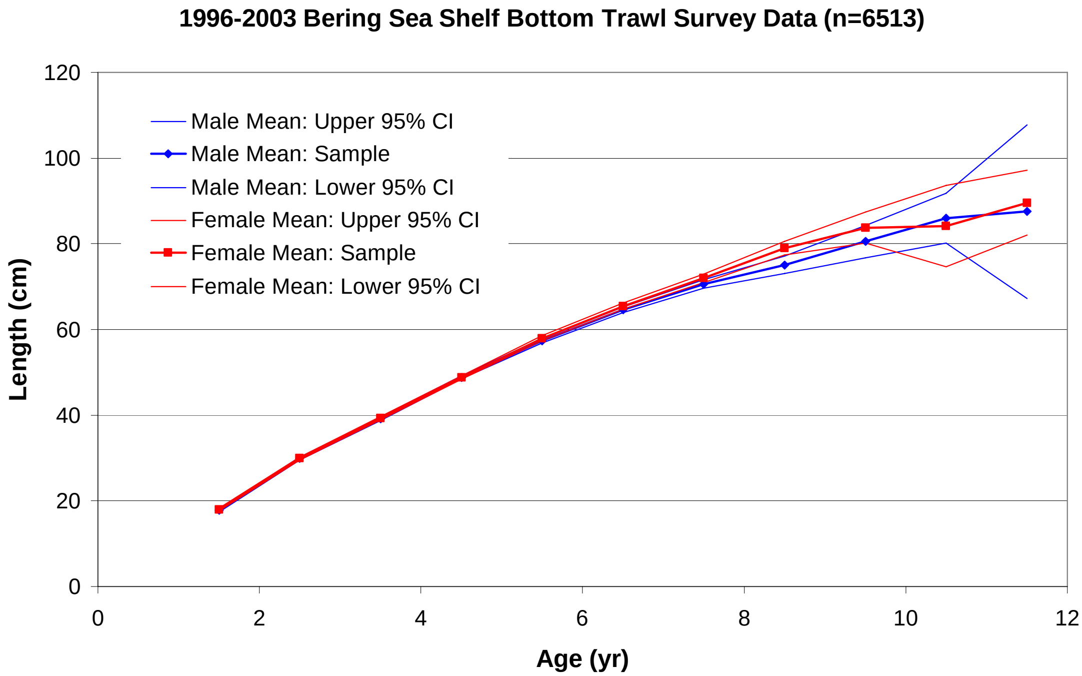

Figure 2.2—Mean EBS Pacific cod length at age by sex, with sex-specific 95% confidence intervals. Values were computed from aggregated age and length data collected during the 1996-2003 shelf bottom trawl surveys. Because these data were collected during summer surveys, ages are shown at mid-year.

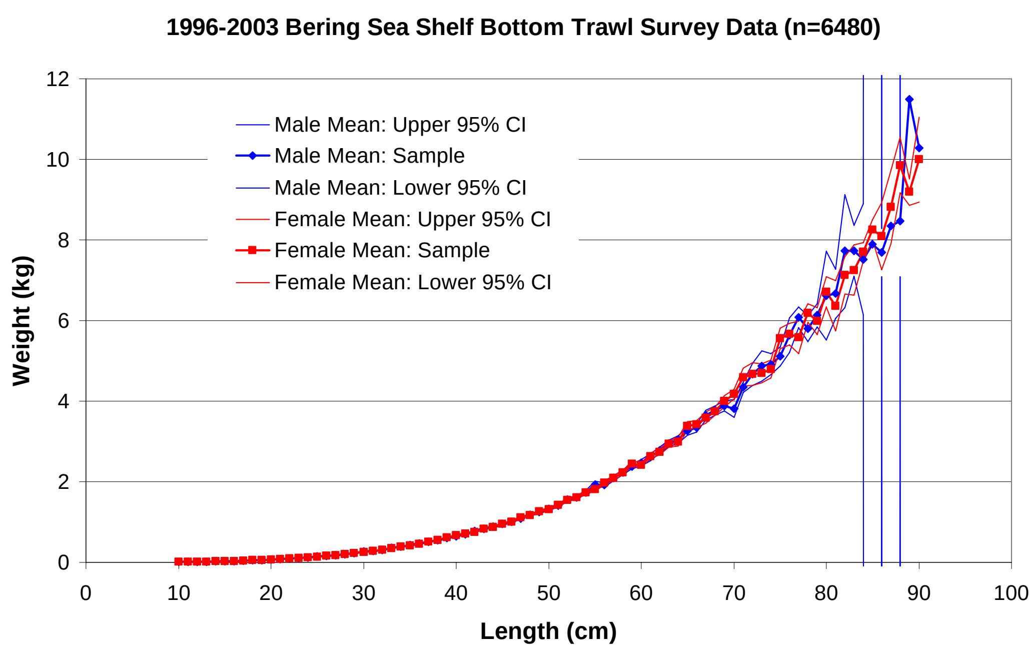

Figure 2.3—Mean EBS Pacific cod weight at length by sex, with sex-specific 95% confidence intervals. Values were computed from aggregated length and weight data collected during the 1996-2003 shelf bottom trawl surveys. Because some sample sizes at higher length values are small, confidence intervals may extend beyond the range of the vertical axis.

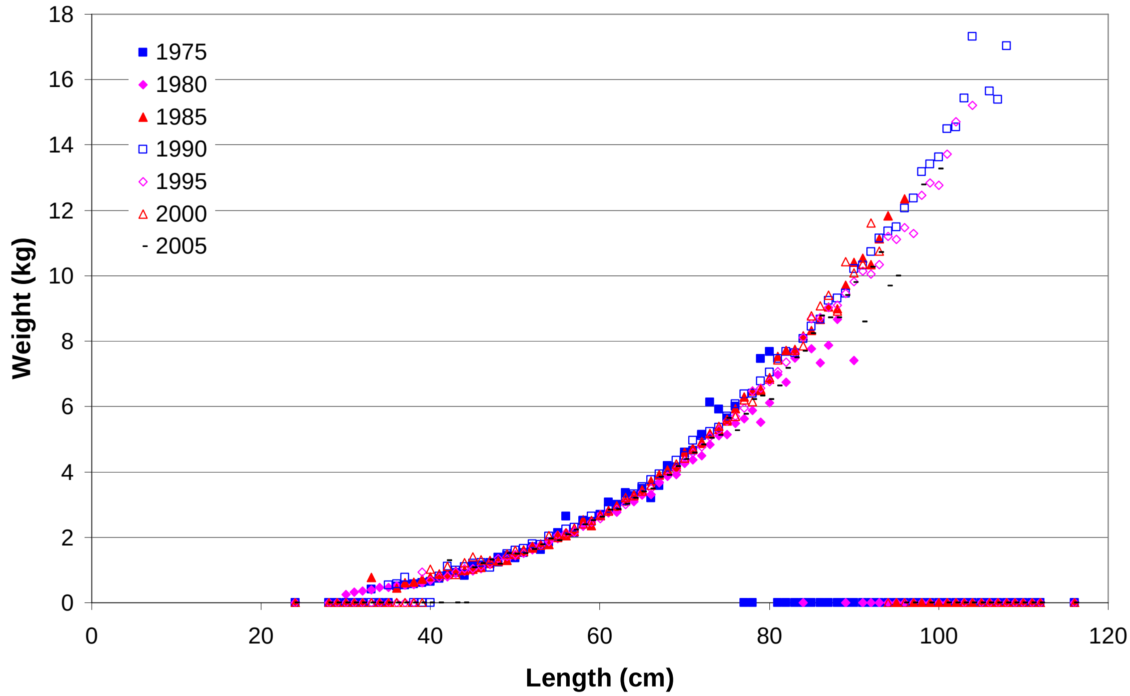

Figure 2.4—Mean EBS Pacific cod commercial fishery weight at length for seven example years. Values were computed from aggregated length and weight data across all gear types and months. Because sample sizes in certain year/length combinations are very small, only those year/length combinations with at least 5 data points are shown.

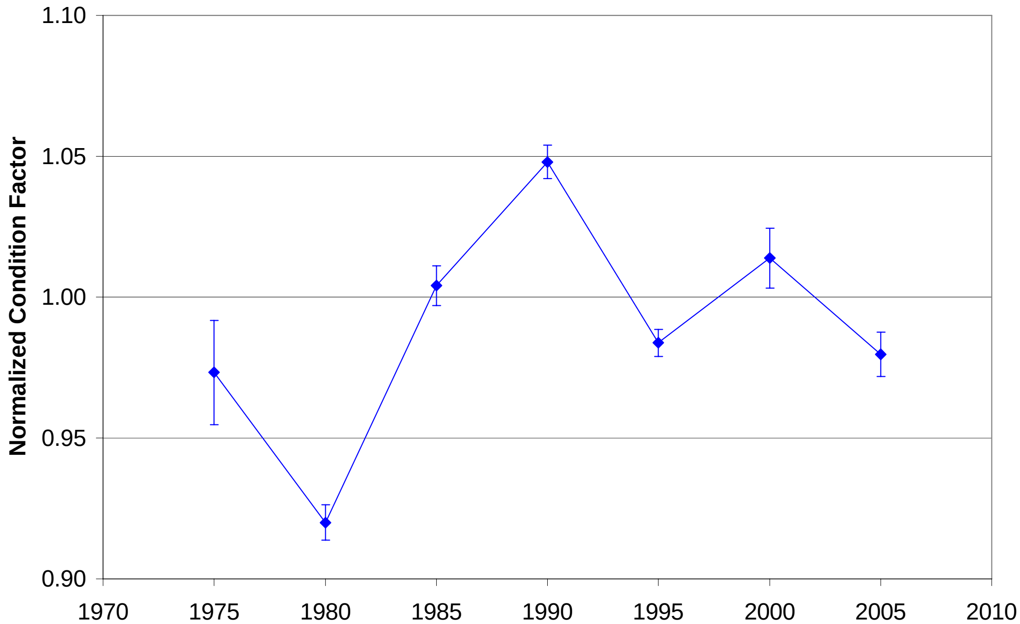

Figure 2.5—Condition factor of EBS Pacific cod for seven example years, with 95% confidence intervals. Condition factor is defined as the average ratio of weight to the cube of length. Values in this figure have been normalized by expressing condition factor as the ratio of the year-specific estimate to the estimate for the entire time series.

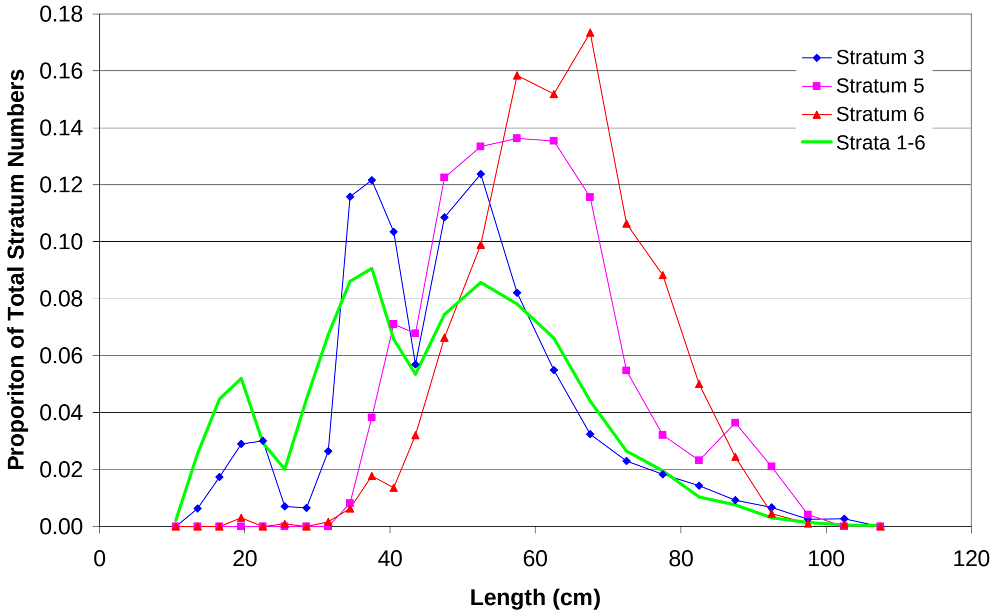

Figure 2.6—Length composition of EBS Pacific cod in the 2004 shelf bottom trawl survey by selected strata and all strata (1-6) combined. Strata 3, 5, and 6 are highlighted here because the observed commercial fishery hauls/sets were concentrated in those strata during 2004 (see Figure 1b). Observed pot hauls were concentrated largely in stratum 5, observed longline sets were concentrated largely in strata 5 and 6, and observed trawl hauls were concentrated largely in strata 3, 5, and 6.

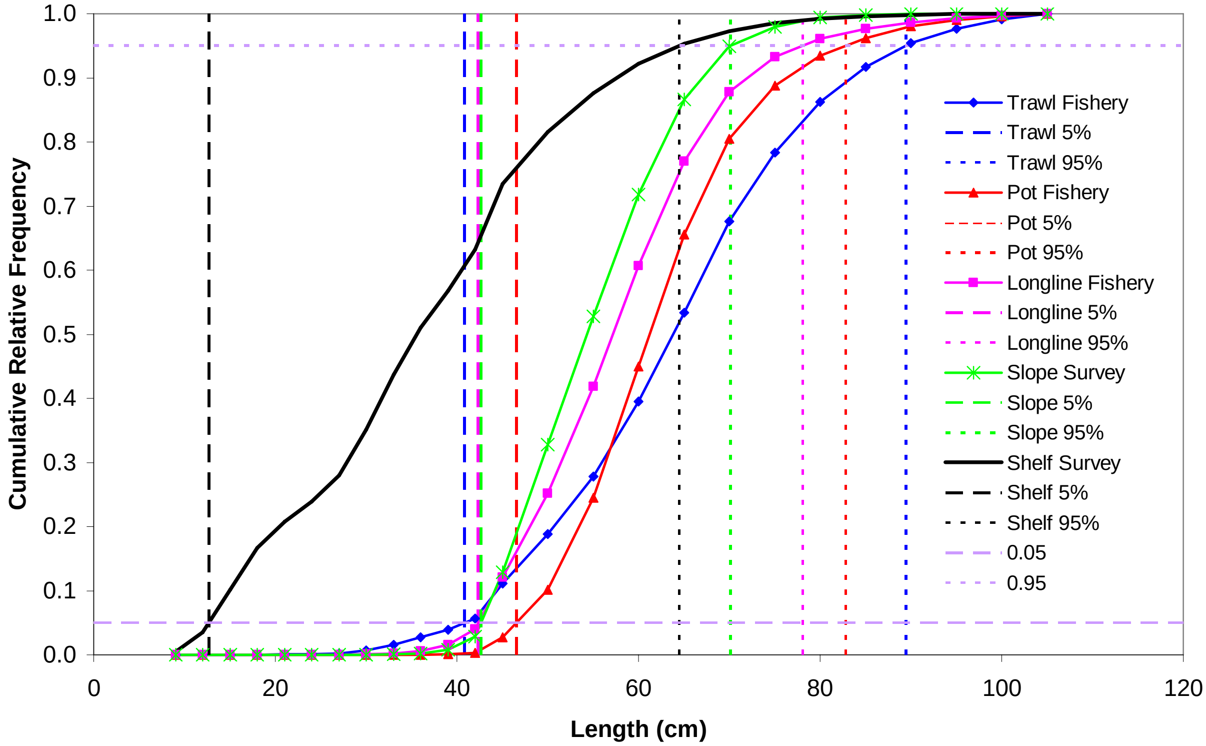

Figure 2.7—Cumulative relative frequencies of EBS Pacific cod lengths observed since 2000. Commercial length frequencies were collected during the January-May fisheries; shelf and slope survey length frequencies were collected during the summer. Solid lines represent the cumulative proportion of lengths observed with the various commercial and survey gears, the horizontal dashed line represents 5%, the horizontal dotted line represents 95%, the vertical dashed lines indicate the length at which the cumulative relative frequency for the corresponding gear equals 5%, and the vertical dotted lines indicate the length at which the cumulative relative frequency for the corresponding gear equals 95%. Thus, the interval between the vertical dashed line and the vertical dotted line for a given gear represents the 90% concentration of lengths for that gear.

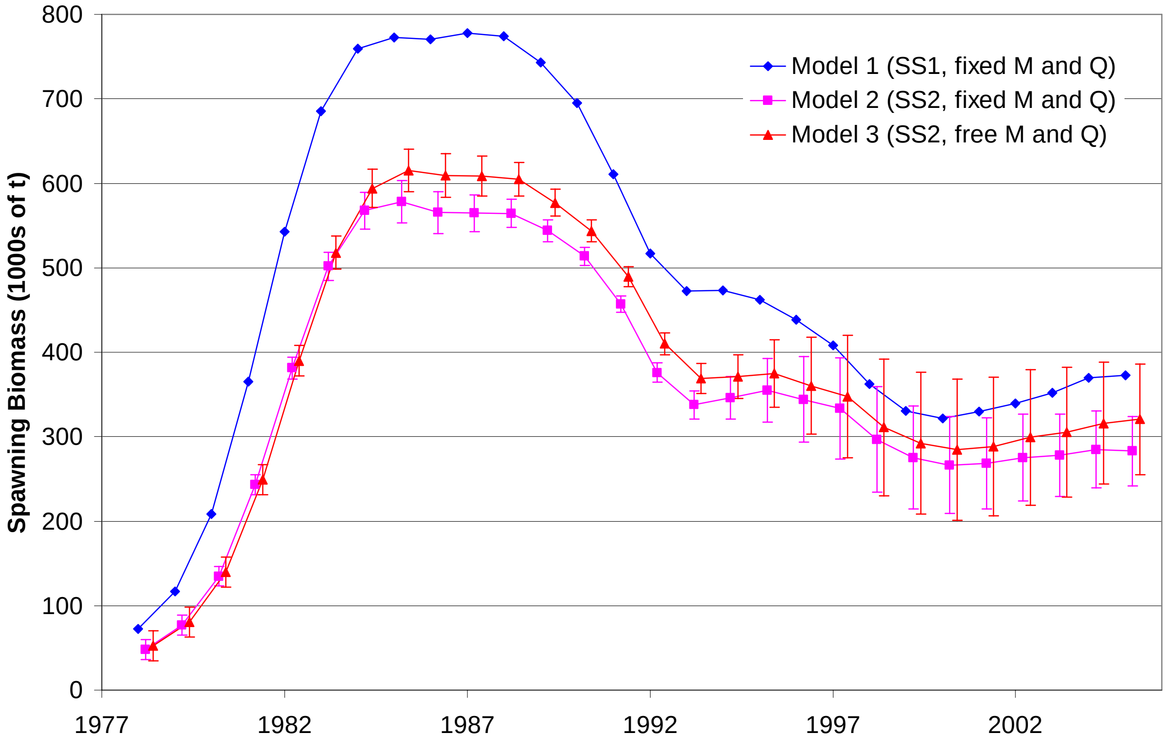

Figure 2.8—Time series of EBS Pacific cod female spawning biomass for 1978-2005 as estimated by Models 1, 2, and 3. The three points for each year have been displaced from one another slightly to improve readability. Error bars for Models 2 and 3 represent 95% confidence intervals (SS1 does not compute confidence intervals).

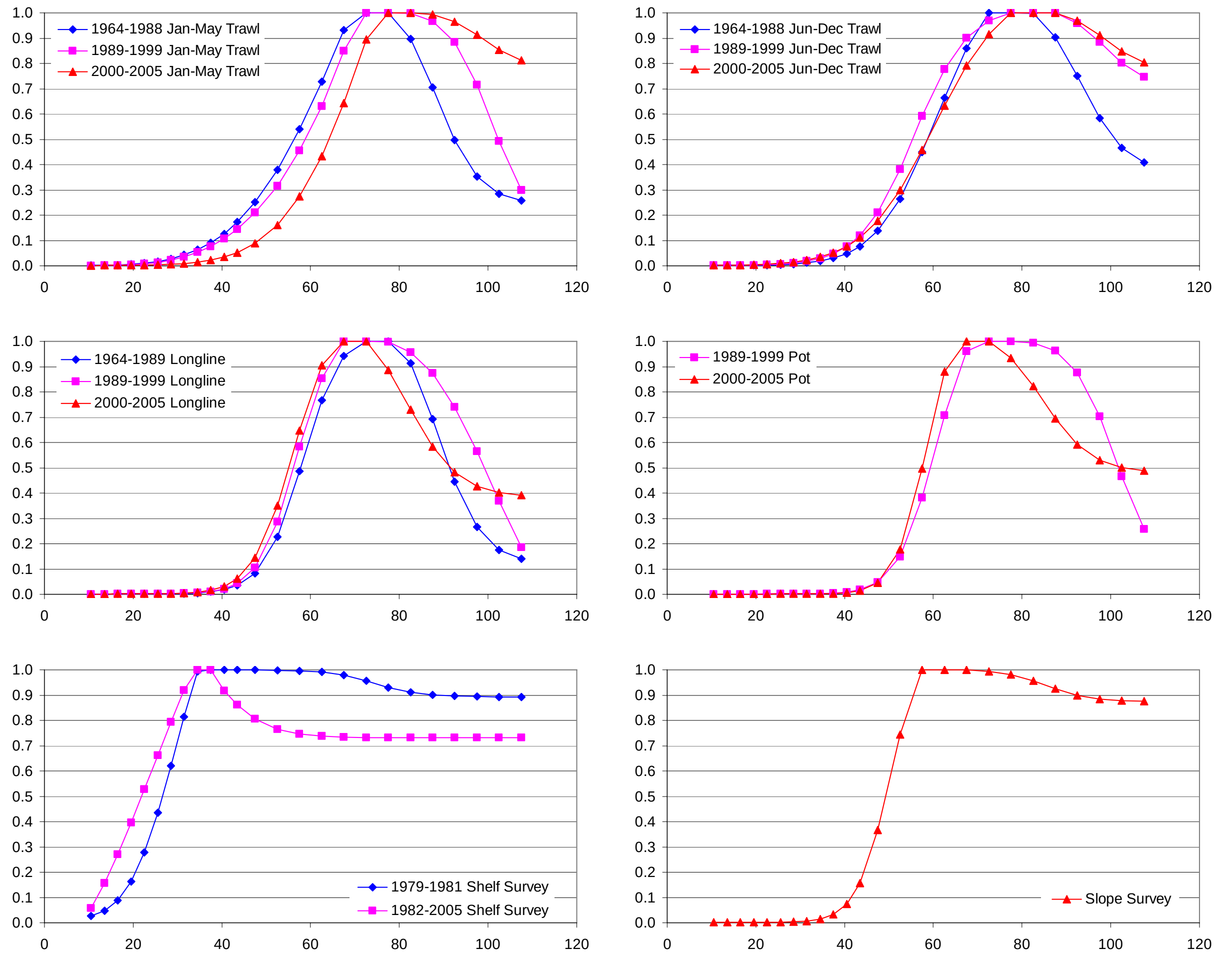

Figure 2.9—Selectivity at length (cm, evaluated at midpoints of length bins) as estimated by Model 3.

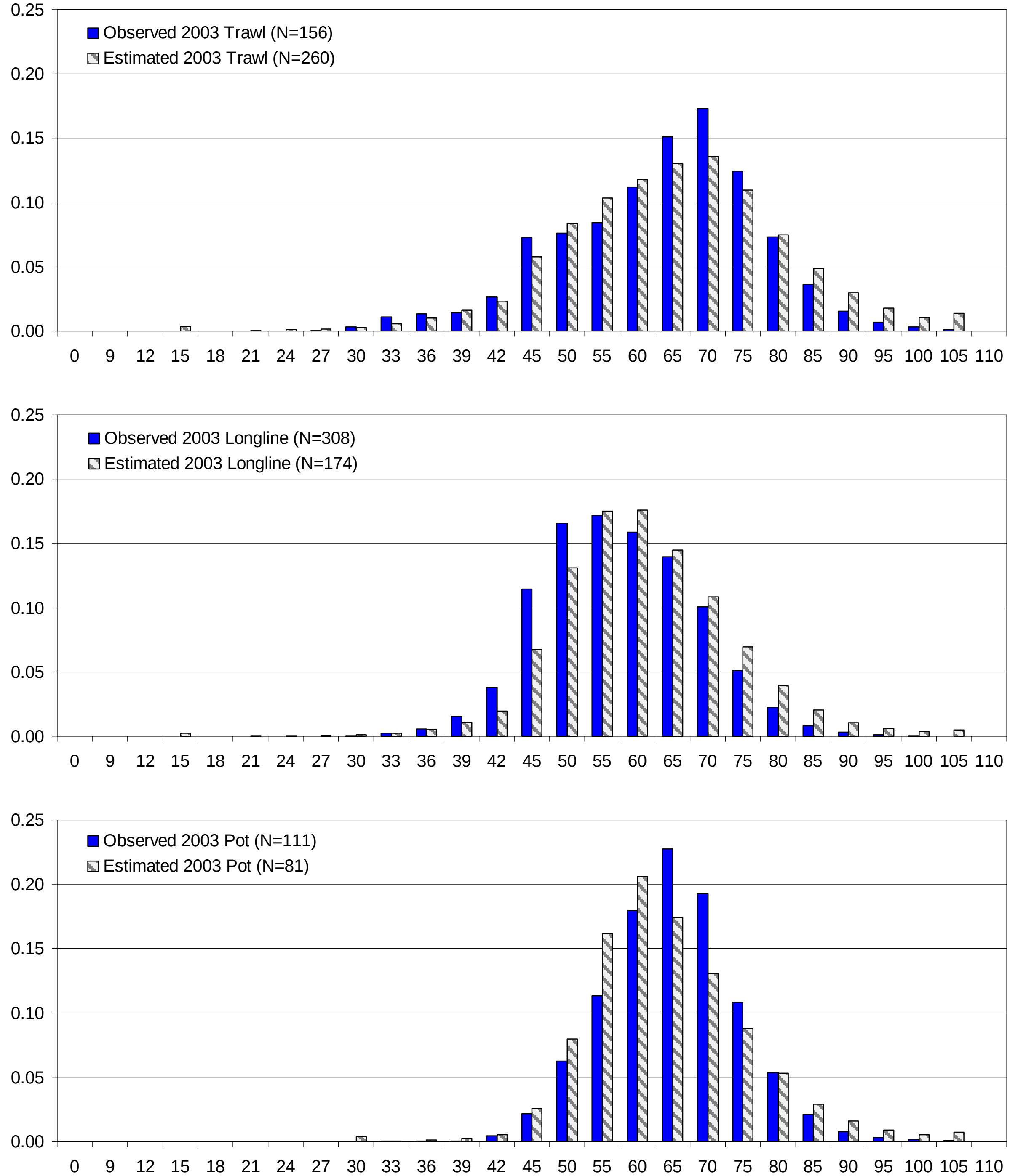

Figure 2.10a—Observed and estimated size compositions from the 2003 January-May fisheries.

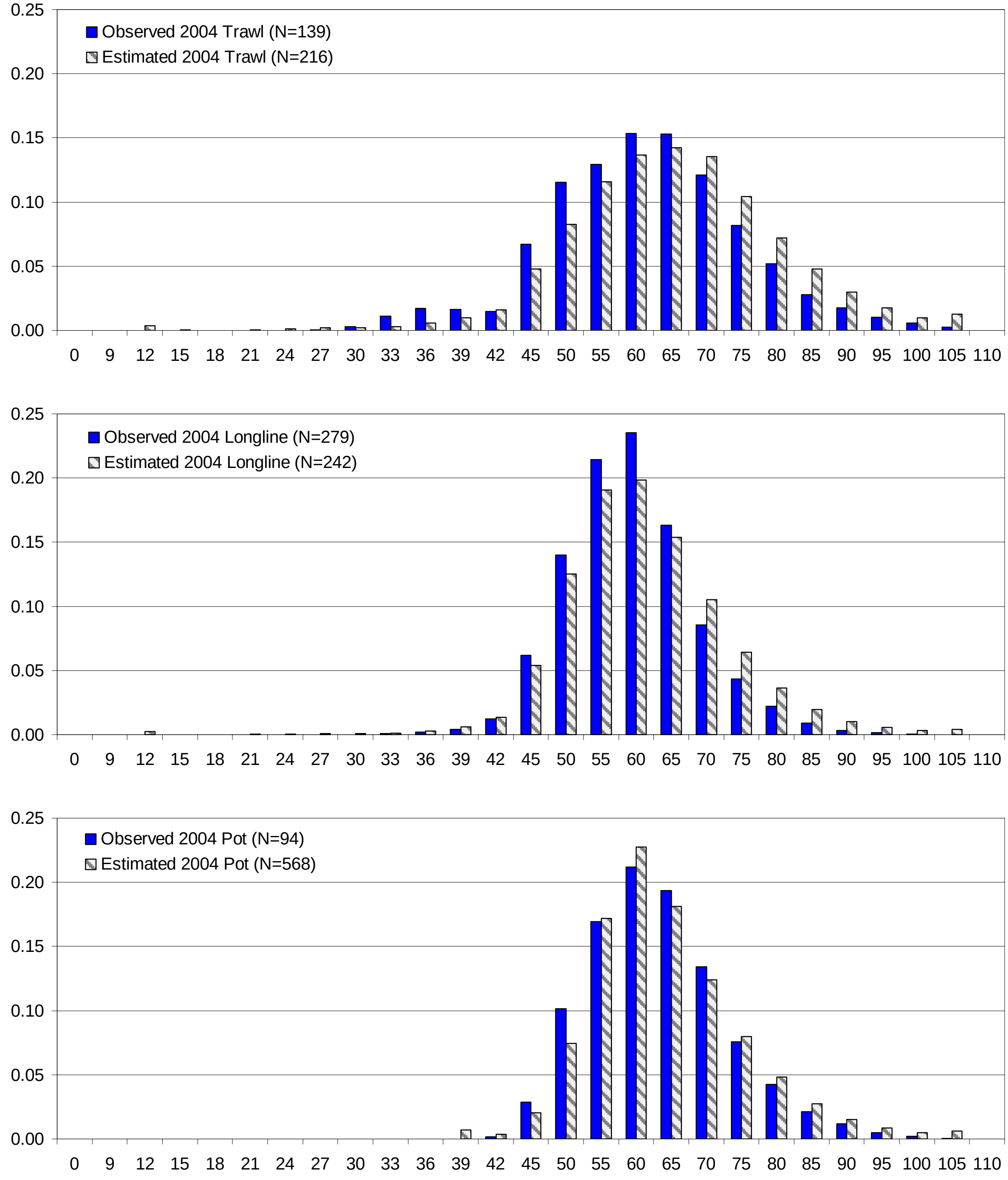

Figure 2.10b—Observed and estimated size compositions from the 2004 January-May fisheries.

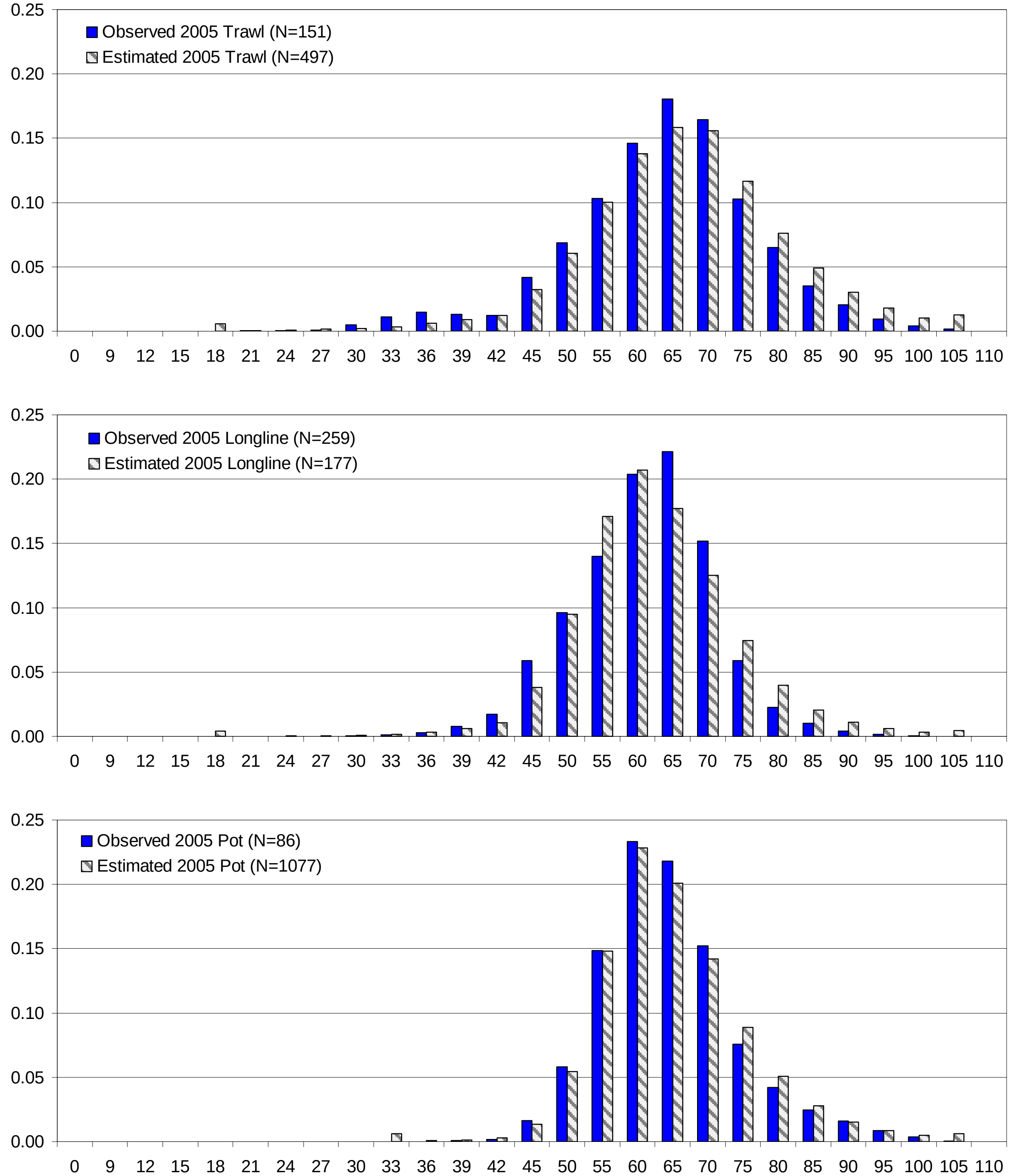

Figure 2.10c—Observed and estimated size compositions from the 2005 January-May fisheries.

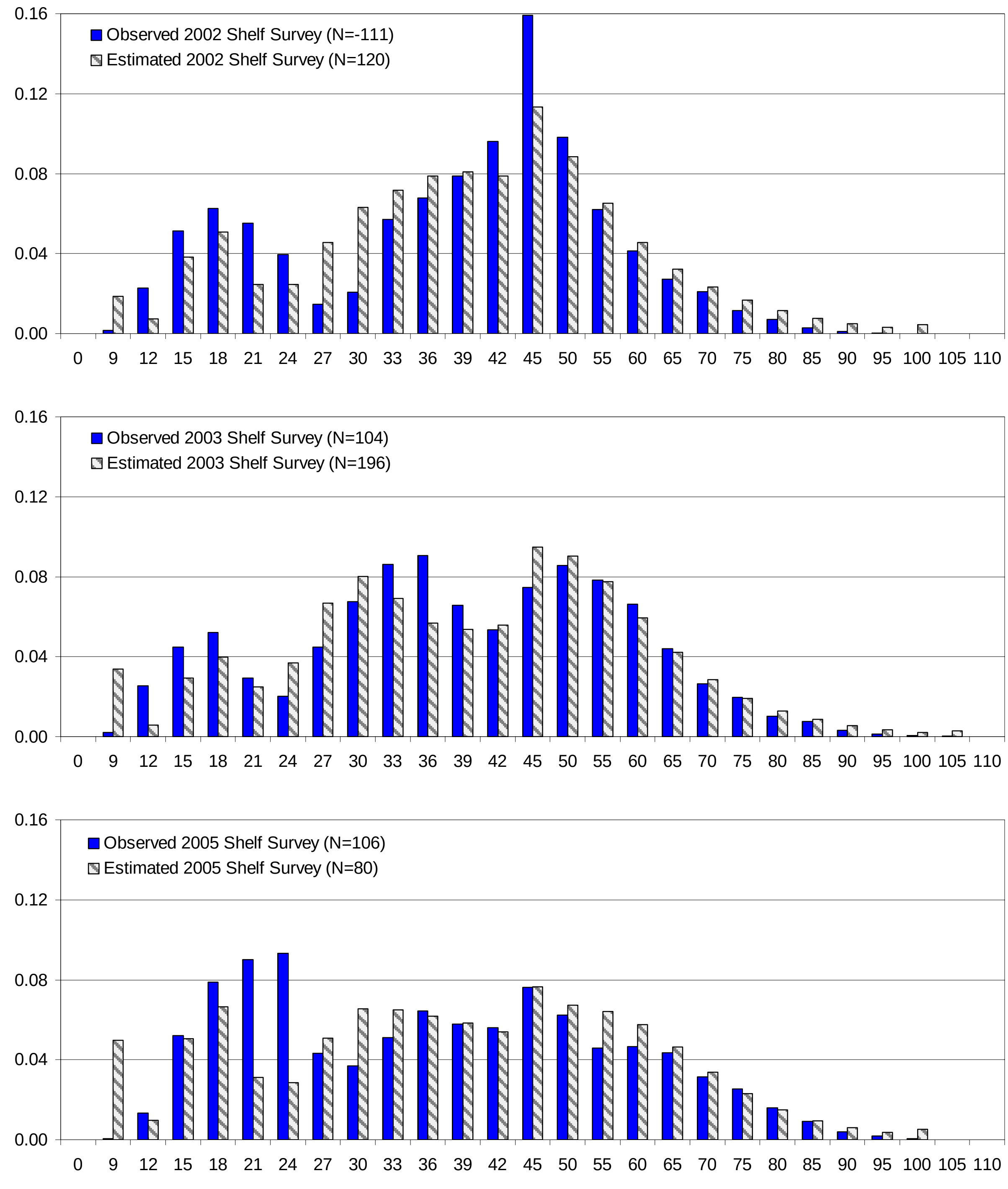

Figure 2.11—Observed and estimated size compositions from the 2003-2005 EBS shelf trawl surveys.

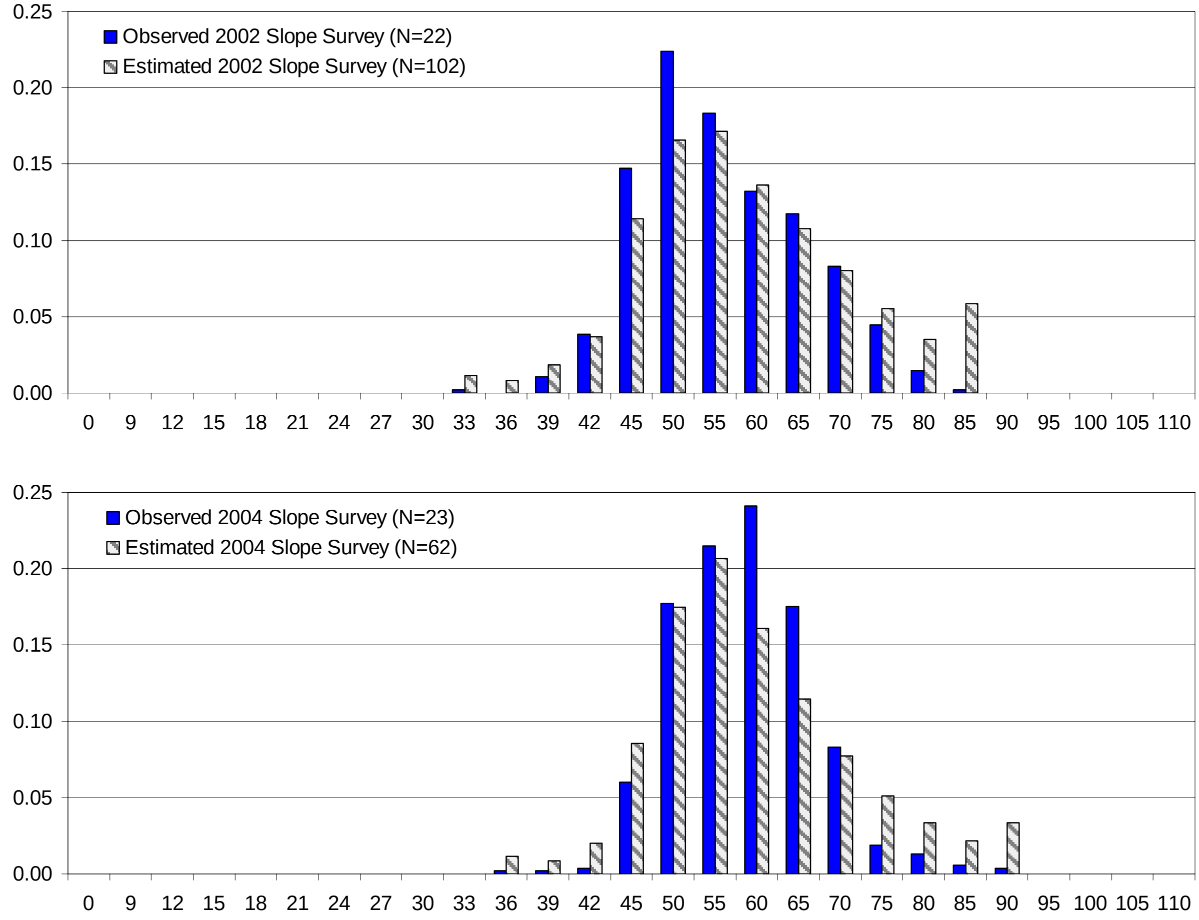

Figure 2.12—Observed and estimated size compositions from the 2002 and 2004 EBS slope trawl surveys.

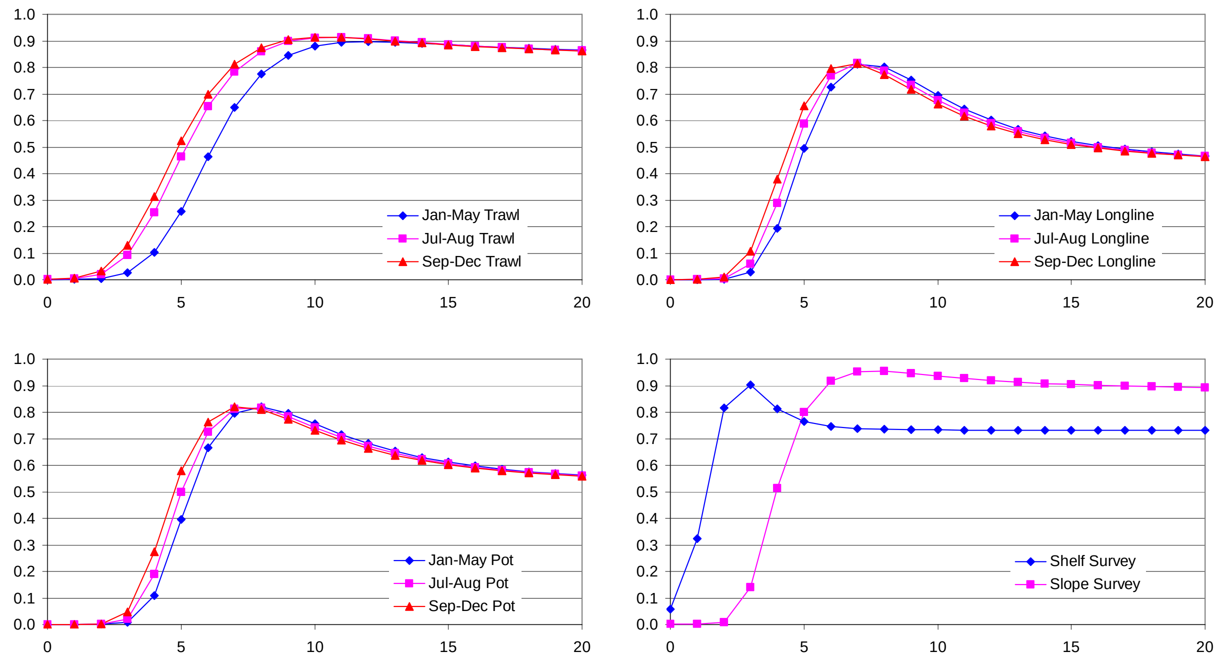

Figure 2.13—Selectivity at age (years) in 2005 as estimated by Model 3. Because selectivity is defined in the model as a function of length rather than age and because a range of lengths are associated with any given age, the above curves do not reach peak values of 1.

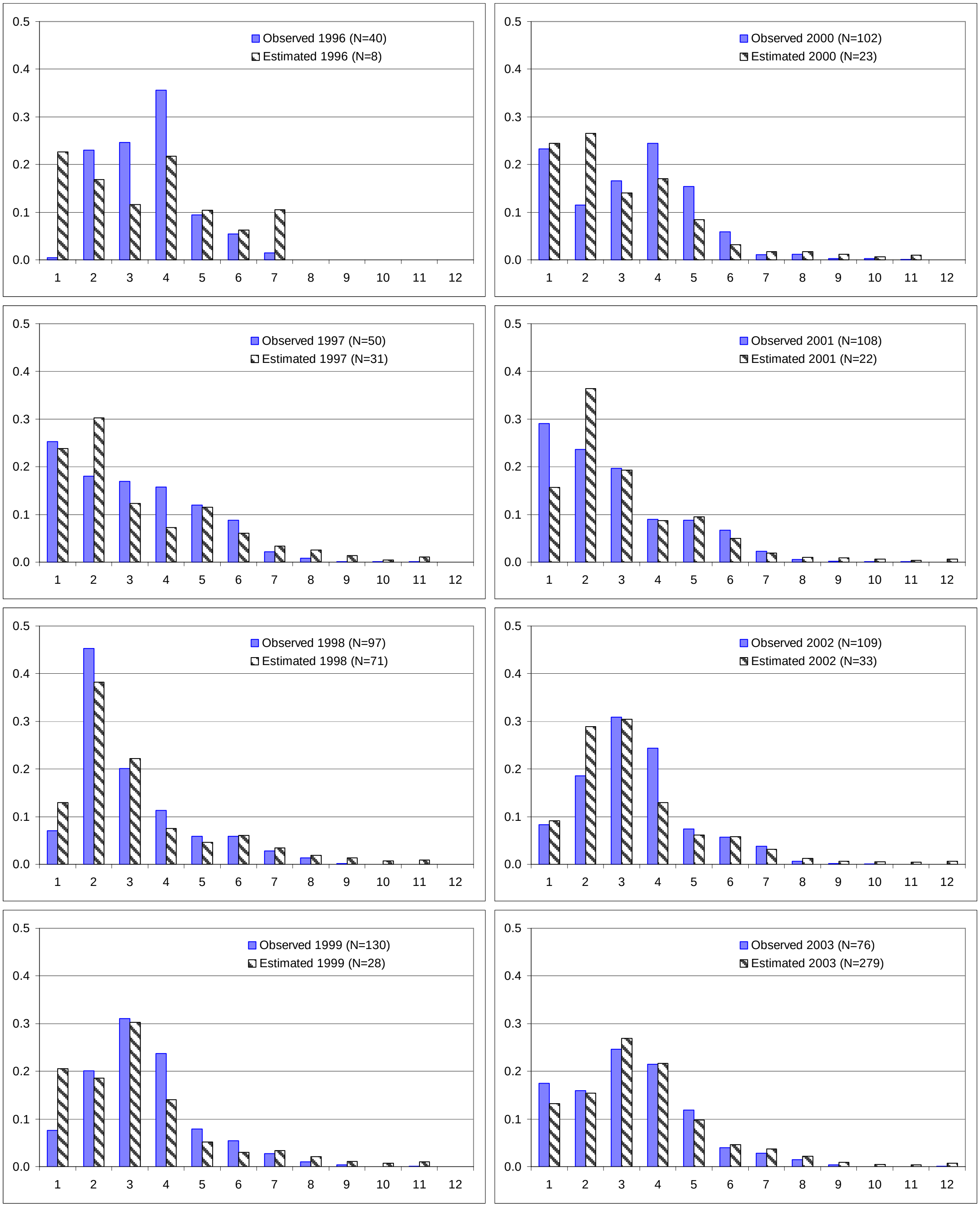

Figure 2.14—Observed and estimated age compositions from the 1996-2003 EBS shelf trawl surveys.

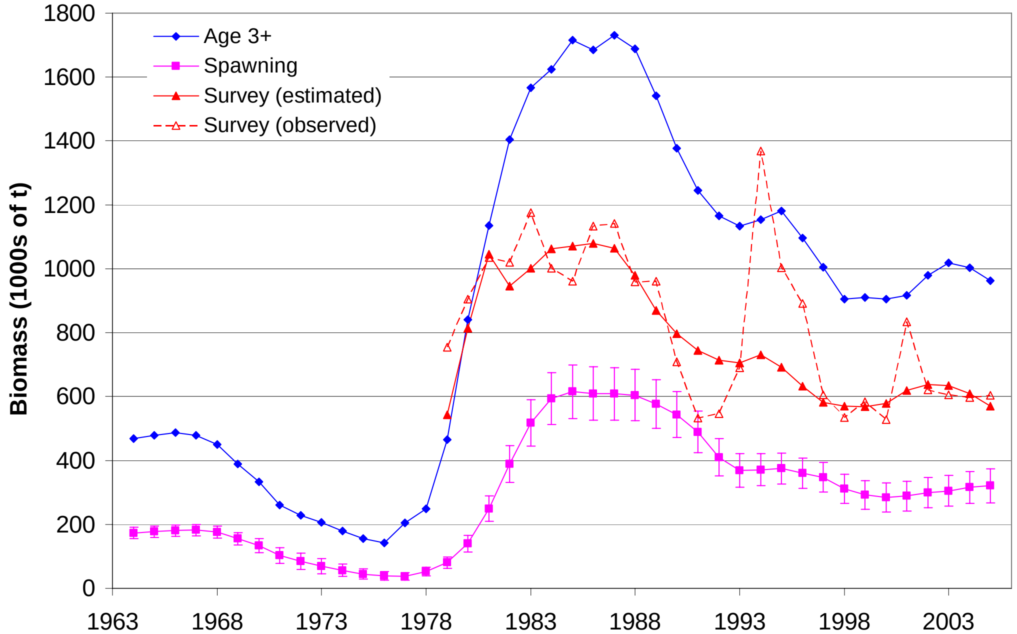

Figure 2.15—Biomass time trends (age 3+ biomass, female spawning biomass, survey biomass) of EBS Pacific cod as estimated by Model 3.

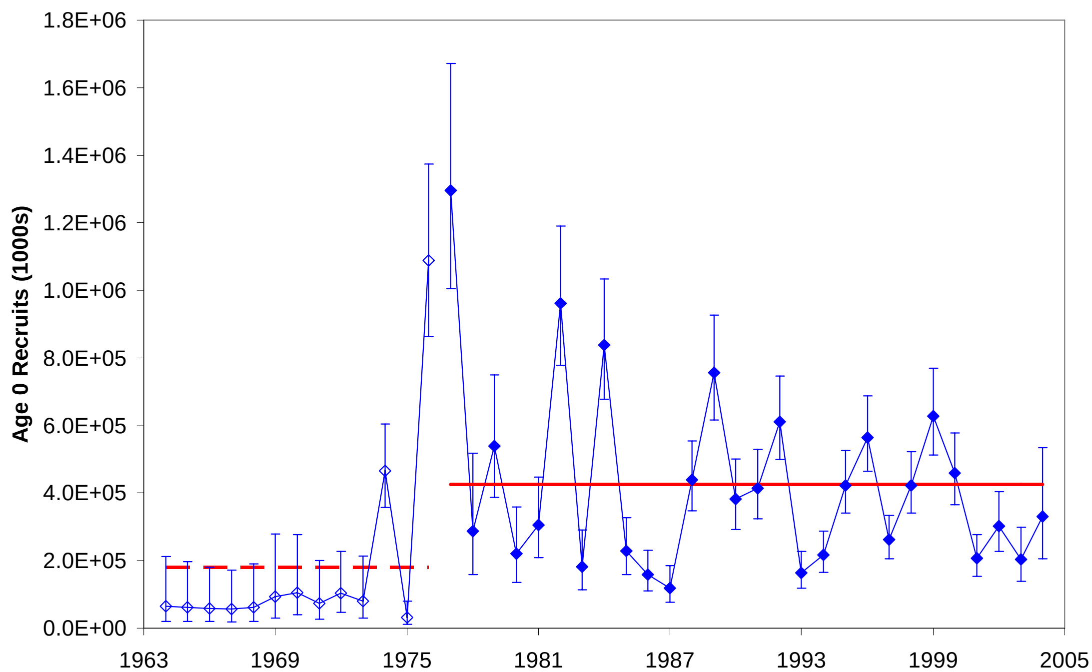

Figure 2.16—Time series of EBS Pacific cod recruitment at age 0, with 95% confidence intervals, as estimated by Model 3.

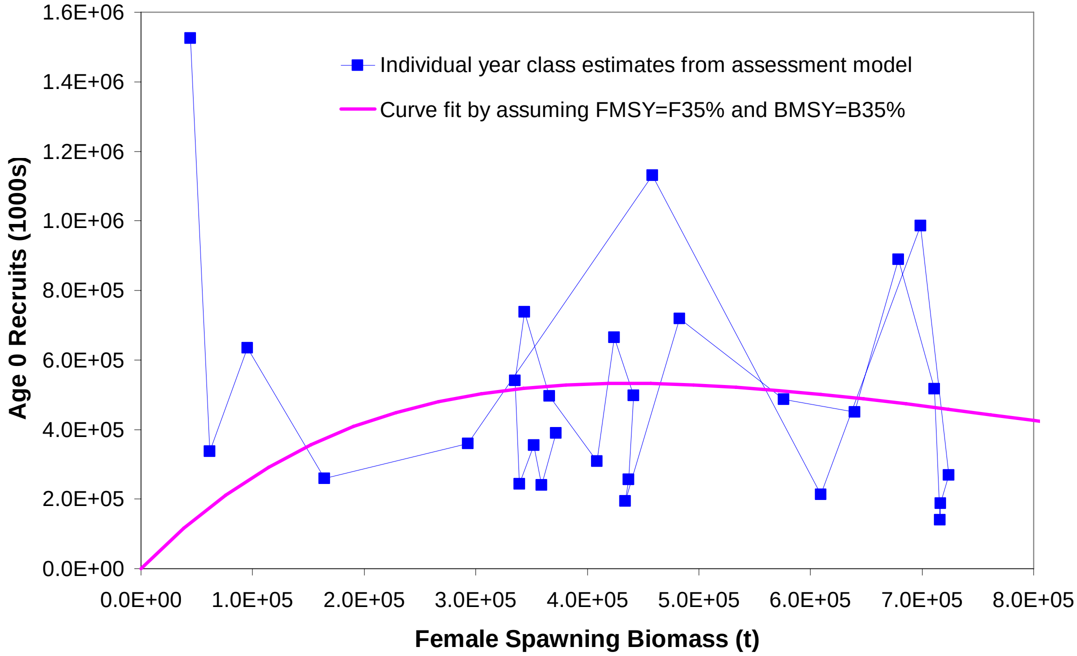

Figure 2.17—Age 0 recruitment versus female spawning biomass for BSAI Pacific cod during the years 1977-2004 as estimated by Model 3, with Ricker stock-recruitment curve fit by assuming $F_{MSY}=F_{35\%}$ and $B_{MSY}=B_{35\%}$.

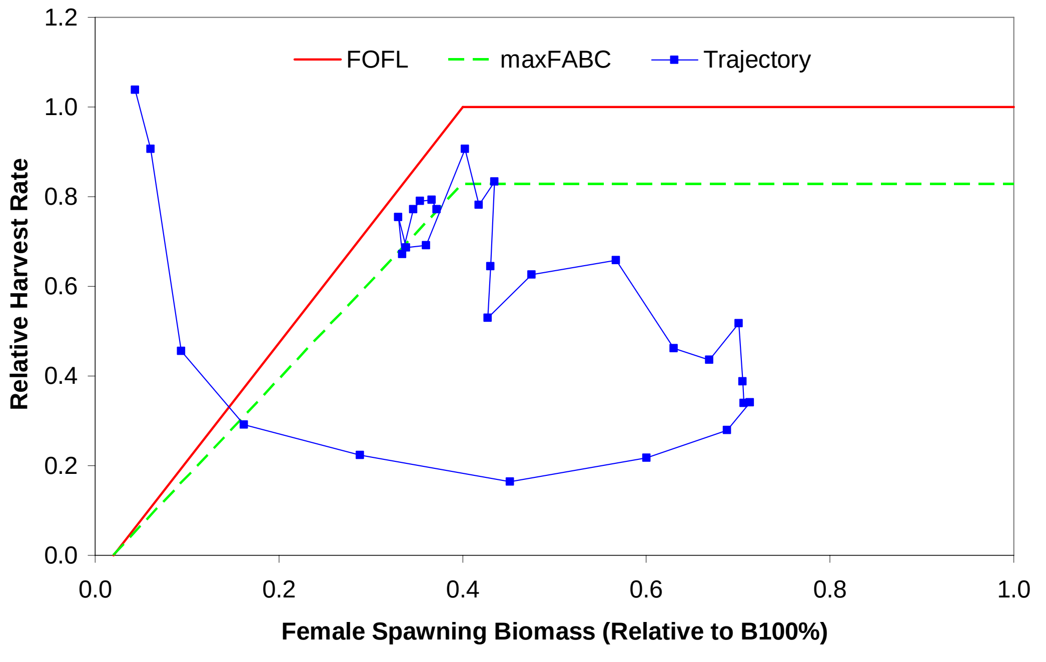

Figure 2.18—Trajectory of BSAI Pacific cod fishing mortality and female spawning biomass as estimated by Model 3, 1977-present.

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